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THE ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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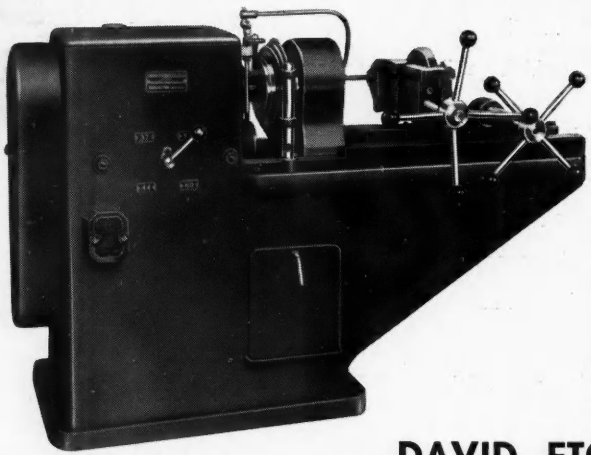

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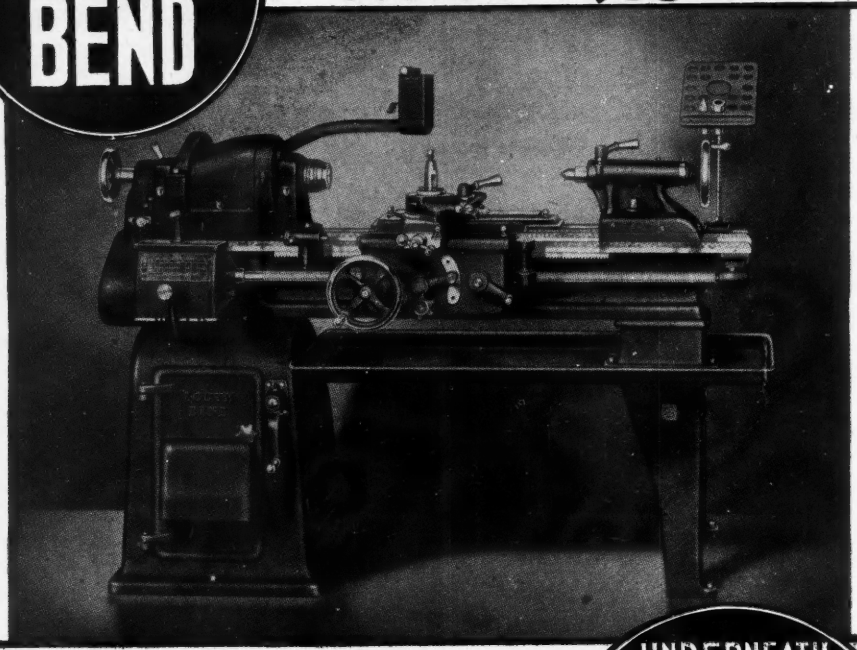

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FUEL SENSITIVITY OF I.C. ENGINES

By Dr. Ing. M. F. Treer. (From *ATZ, Automobiltechnische Zeitschrift*, Vol. 44, No. 20, October, 1941 pp. 514-515).

The progress of I.C. engine performance was marked by continuous improvement of the engine and a careful selection of the best suitable fuel for optimum performance. War-time fuel shortage, however, has modified this progress, inasmuch that now the engines are re-designed in order to give optimum results with the available stocks of fuels. This especially applies to countries like Germany, where more than 95% of the fuel consumption is limited to home production and the production of the occupied countries. It seems pertinent, therefore, to investigate the requirements of various types of I.C. engines with regard to the more important fuel characteristics.

The two factors affecting fuel sensitivity of engines are: the method of igniting the charge, and the method and timing of mixing the fuel-air charge. From this it follows that the engines can be grouped for the present investigations as carburetted engines, high pressure injection and low-pressure injection engines. Also, the various factors affecting the efficiency of a particular engine were neglected for this purpose, and engine performance was studied from the view of combustion efficiency only, that is, what proportion of the energy introduced into the cylinder was being converted to mechanical energy by combustion.

The "Otto" Engine. Characteristic to engines working on the Otto cycle is the imperative necessity for a complete evaporation of the fuel, including small fuel droplets adhering to the cylinder walls. To satisfy this requirement, the fuel should have a low boiling point, and this characteristic will set a limitation to the types of fuel that can be used in such engines.

Detonation, or property of knocking, gives rise to yet another limitation, inasmuch that knocking being greatly affected by the compression ratio of the engine, fuels with an Octane number less than 30 cannot be effectively used.

Within the above limitations, namely boiling point temperature and Octane number, carburretted engines show a remarkably good performance. Energy losses due to incomplete combustion are estimated to be not more than 1-2%, and due to sensible heat transferred to the cylinder walls, etc., about 4-5%. In all the combustion efficiency of such engines is therefore round about 94%.

Diesel Engines. Totally different is the case with Diesel engines, which can be made to run even on solid fuels, such as powdered carbon provided certain designing features are incorporated. No limitation is therefore set to the selection of Diesel fuels as far as boiling point temperature is concerned.

Analogous to detonation in carburetted engines, the self-ignition temperature of the fuel is a most important factor for Diesels. If self-ignition temperature is too high, the engine cannot be started, or if this is made possible by special arrangements, the running of the engine becomes most irregular and unsatisfactory. In general, therefore, Diesel fuels should have a Cetane number not less than 35.

The combustion efficiency of Diesel engines is not so high as that of petrol engines owing to the difficulty of proper mixing of the fuel/air charge. The heat losses to the cylinder wall are increased, too, by the higher combustion temperature of Diesels compared with petrol engines.

Low-Pressure Injection Engines. The fuel is injected into the combustion space while ignition is initiated by means of spark plugs or other external device. A notable feature of these engines is that they can use all classes of fuel, provided of course that it is suitable for injection. This does not mean, naturally, that the fuel can be changed from a diesel oil to a light petrol without affecting the engine performance, but that the engine does not require any special design when the fuel is changed over, certain adjustments being of course necessary (compression ratio, timing of injection, etc.). It can be said that this type of engine takes up an intermediate position between carburetted and high pressure injection engines. If the fuel has a low boiling point temperature, then injection can take place early and a very thorough mixing of the charge results and the performance is similar to that of a high pressure injection engine. Owing to the danger of detonation, however, the compression ratio must be kept at a low value.

If the fuel has a low ignition temperature and high compression ratio is to be used, then the possibility of detonation must be prevented by constructional details. The mixing becomes inferior, the volumetric efficiency is reduced, and in general the engine operates as a high pressure injection engine.

A recently designed, injection type, two-stroke, hot-bulb engine was tested as regards to efficiency. The mechanical efficiency of the

engine proved to be most satisfactory, being of the order of 80% (overall). In Table I. the fuels examined with this engine are tabulated, and Fig. 1 shows the evaporation curves for the fuels.

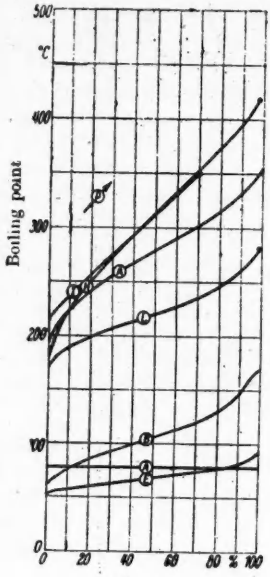


Fig. 1

The experiments showed that at reduced loads (high percentage excess air) all the fuels behaved in a similar manner, but at full load combustion became the more incomplete the higher the boiling point temperature of the fuel. Similar behaviour was noted recently with Diesel engines, but the question has not been adequately investigated to draw a general conclusion. Also the efficiency of the engine at medium working pressures (3 atm.) was excellent with fuels of low boiling point temperature and fell off as evaporation of the fuel becomes more difficult (Fig. 2).

In Fig. 2 results obtained with all three types of engines are plotted. Under favorable condition all types of engines can be run with a high efficiency, but fuels of a boiling point above 180° C cannot be used in Otto engines, while for Diesels a low self-ignition temperature is most essential. Injection type of engines on the other hand can be run on all fuels that can be injected. The phenomenon of knocking is important with all three types of engines. The lower limits are 30 Octane No. for the petrol engines, and 35 Cetane No. for the Diesels, while the low pressure injection engine has its limitations in so far as the timing of injection and the compression ratio, etc., must be readjusted before the fuel is changed over.

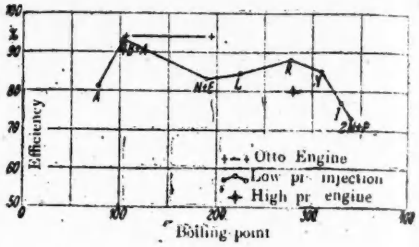


Fig. 2

TABLE I.

Type	Density	Lower Cal. value
E	0.947	8000
A	0.794	6400
B	0.73	10,200
L	0.816	10,200
R	0.835	10,200
N	0.884	10,200
I	0.89	10,000
P	0.91	9850

ADOPTING A NEW RAIL-ROLLING PROCESS

By P. A. ALEXANDROV. (From *Stal*, Moscow, 1941, No. 4, pp. 35-41).

THE Petrovsky Steel Works recently decided to introduce the new rail-rolling trains first proposed a few years ago by Bartscherer, and, although difficulties were at first encountered, and some modifications found necessary, their adoption has been well justified.

The original proposal will be clear at a glance from Fig. 1, and its advantage lies in more thorough modification of the primary structure and greater compactness of metal at the centre of the flange and bulb. At the same time the number and distribution of hair seams is changed in such a way as to render them innocuous : they are fewer and lie almost parallel to the outer surface of the bloom, instead of being perpendicular to it. The idea is to roll a deep groove on the flange face of the bloom and form the

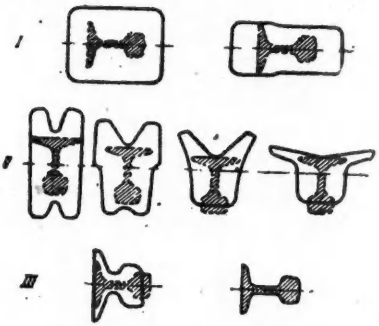


Fig. 1. Diagram of successive deformations for the Bartscherer rail-rolling process. I.—Blooming mill passes ; II.—Roughing passes ; III.—Finishing.

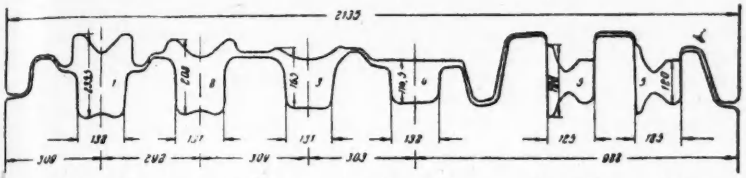


Fig. 2
Roller profiles for first four passes for rolling Vignoles IA type rails by the Bartscherer method at the Petrovsky works.

flange by parting the metal sideways from it, while a somewhat shallower groove at the head of the rail is used exclusively to consolidate the metal, and is subsequently obliterated.

In practice it was found that the deep grooves on the lines of Fig. 1 marked the metal too hard and remained in the form of a slight depression on the bulb of the finished rail and a similar depression or a fold in the middle of the flange. It was also found unnecessary to start with slabs having a widened portion corresponding to the flange (as shown in the top right hand corner of Fig. 1), because the parting process gave more than enough metal for flange formation : in fact, there was some difficulty at first with excess metal in this region, involving modification of the second roughing pass.

Eventually, therefore, the rolling profiles became as shown in Fig. 2, and the slab used was a simple rectangle, 240×135 mms. It will be noted that the bottom groove was made far less prominent and the parting process rendered more gradual.

The process of parting, shown in detail in Fig. 3, was found to require considerable attention because while the number of passes had to be kept small for practical reasons, too sudden changes were found to result in the metal flowing inwards and forming seams at the centre of the flange.

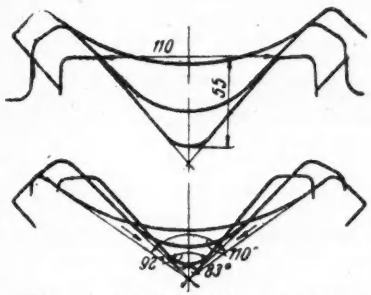


Fig. 3. Diagram of parting and spreading angles in the early passes.

Production according to the new rolling scheme was distinctly slower before, but for reasons which can be remedied. Apart from general lack of experience there was trouble with the narrow slabs which had to be fed into the rolls edge-on falling over on one side, and with the turning over operation between passes No. 4 and No. 5, which had to be done by hand. It was felt advisable, moreover, to use an increased number of passes (19 instead of the former 17), while the process was in its experimental stages.

The resulting slowing down meant that the last stages of rolling were done at unusually low temperatures, and this way have affected to some extent the test results discussed below.

Table I. shows the results of the inspection of a large number of rails rolled by the two methods.

TABLE I.

Process		Total Inspected	Passed 1st Class	Defective					
				Tearing	Flaking	Blister	Profile	Sand	Total
OLD Process	No. off	373	312	30	25	3	—	3	61
	%	100	83.7	8	6.7	0.8	—	0.8	16.3
NEW Process	No. off	384	311	29	17	—	26	1	73
	%	100	81	7.5	4.4	—	6.8	0.3	19

Although the new process here exhibits a slightly greater percentage of defective lengths, it should be noted that there is an item of 26 rails or 6.8% for defective profiles which arose from poor adjustment of the rollers in the early stages. Discounting this, the number of defective rails could become very appreciably lower for the new process than for the old.

Samples were next taken from 19 melts rolled by the new process and 15 melts of the old, and the following tests applied :

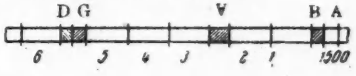
(1) The "Swiss" test for flange strength in bending (see Fig. 5).

(2) Deep etching examination of lower surface of flange.

(3) Etching by the Oberhoffer method for the examination of primary structure.

(4) Impact strength tests using a Charpy type pendulum.

(5) Microscopic examination.



Rail—Forward end

Fig. 4. A = Impact test specimen ; B = Specimen for mechanical tests ; V & G = Specimens for impact tests, "Swiss" tests, fatigue, and Oberhoffer macro-structure.

The samples were taken out as per Fig. 4, and the most interesting results were as follows:

Swiss Tests. 2 rail sections 100 mm. long with machined ends were taken from each melt and tested in a 300 ton hydraulic press in a manner which will be clear from Fig. 5. The distance between supporting rollers was kept at 100 mms. and the rail was loaded up until the deflection at the centre of the flange became 8 mms., and intermediate reading being taken with 3 mms. deflection. If failure occurred before the standard deflection was reached, the load and pointer position at the moment of failure were noted.

As a general rule the permanent set after release of load was 1.0 to 1.2 mms. less than the deflection under load.

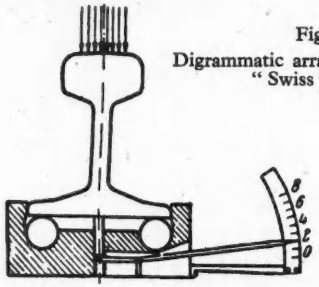


Fig. 5
Digrammatic arrangement of the "Swiss" test.

The results, summarised in Table II., were most striking. It will be seen that whereas only 18% of the "old process" rails survived the 8 mm. deflection, the corresponding figure for the new process was 72%. At the same time the number of rails which were able to stand up without damage to a permanent set of 3 mms. (corresponding to 4 mm. total deflection) increased from 79% to 95%. This was of particular interest as that amount of permanent set is called for in the proposed new U.S.S.R. Standard Specification.

TABLE II.

Process	No. of specimens (%) which broke deflection in mms. was under					Specimens which have survived 8 mm. deflection %
	<4	4-5	5-6	6-7	6-8	
OLD ..	5.1	2.5	5.1	7.7	7.7	71.8
NEW ..	21.4	7.1	17.9	17.9	17.9	17.9

Another very interesting comparison was obtained by plotting the loads required to produce a given deflection against Σ (C — 0.25 Mn) as shown in Fig. 6: it is clear that for any given composition of steel the new process rails are consistently stiffer, often by a considerable margin.

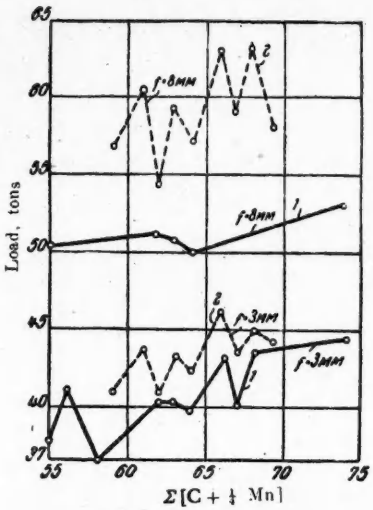


Fig. 6
Results of "Swiss" tests:
1— Old process,
2— New process.

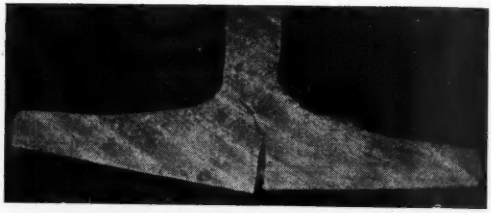


Fig. 7. Typical flange fracture for old process rails.

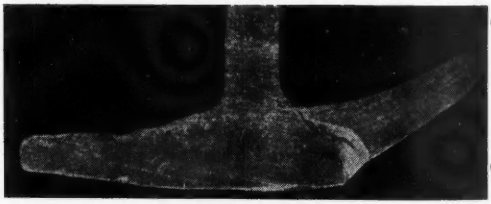


Fig. 8. Typical flange fracture for new process rails.

The character of fracture was also different, as will be seen from Figs. 7 and 8, the old process rails generally broke right in the middle of the flange and perpendicularly to it, while with the new process, the fracture was inclined and occurred at about the boundary of the middle-third region.

Deep Etching of Lower Surface. Specimens of 500 mms. length were etched in a 30% solution of muriatic acid. The bottom surface of the flange was divided into three equal strips by longitudinal lines and then, in a region which

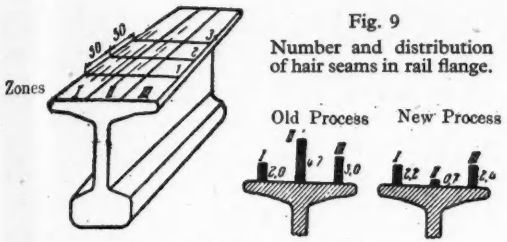


Fig. 9
Number and distribution of hair seams in rail flange.

appeared to be typical, three transverse lines were drawn, 50 mms. apart, as shown in Fig. 9.

The number of hair seams (blisters) crossing each transverse line was then counted and the results averaged out as indicated in the diagram. It will be noted that the average number of hair seams per cross-section is much smaller with the new process (5.3 instead of 9.7 total) and they are located moreover almost entirely along the sides. Thus the number of such seams in the middle third region is reduced from 4.7 to 0.7 by the change in rolling methods.

It is clear, therefore, that with the new process the blisters located in that part of the bloom which later becomes the middle-third region of the rail flange are forced to the surface and eventually obliterated by the more drastic squeezing which the metal here receives in the " parting" process. This is of considerable advantage, since defects near the middle of the flange are more dangerous than any other from the point of view of causing failure in service.

Etching to Bring out Primary Structure. The study of macro-structure, with the aid of the Oberhoffer reagent confirmed that the old process rails were typified by column-like crystal formations running perpendicularly to the bottom surface of the flange near its centre and penetrating as deep as 15 mms. Near the surface there were segregations running from the hair seams inwards.

The structure of new process rails is quite different. Here the segregations are flattened out and often drawn out almost parallel to the lower surface and the crystal columns are thoroughly broken up.

Impact Tests. These were made on a Charpy pendulum testing machine with Mesnager type of specimen and the notches were cut in two different ways, as indicated in Fig. 10. The results, as plotted in Fig. 11, show greatly improved strength of new process mils.

Fig. 10 Diagrammatic representation of the two ways of cutting the notches for impact specimens.

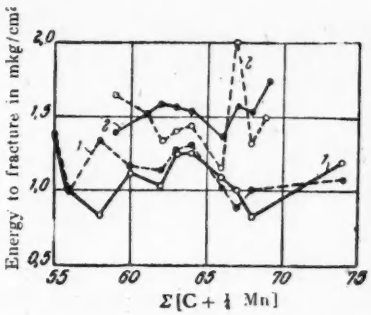


Fig. 11. Impact fracture energy (at 20 C) of specimens as follows: 1—Old process rails; 2—New process rails, ——Notch parallel to flange surface, - - - - Notch perpendicular to flange surface.

The comparison in this case is not entirely fair, because the temperatures at which the rolling was done were, as previously mentioned, somewhat different for the two processes, and this might have favoured the rails made by the new process so far as this particular series of tests was concerned. However, similar tests made at the Dzcrzhinsky Works, where there were no such temperature differences, yielded very much the same results, conclusively establishing the improved toughness obtained by the new process.

Microscopic Examination. Specimens were cut from the middle-third region of the flange, and photographs shown in Figs. 12 and 13 are typical of the different dispositions of hair seams: Fig. 12, typical of the old process, shows the remains of a thoroughly welded blister running

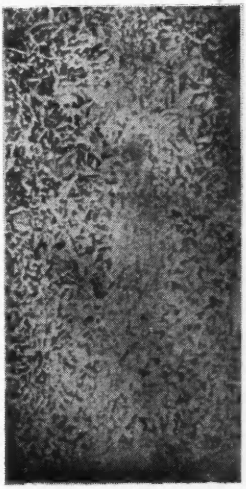
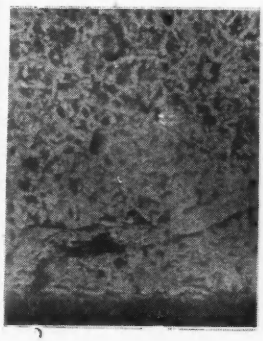


Fig. 12 (at the left) welded blister (hair seam) in old process rails.

Fig. 13 (at the bottom). Hair seam in new process rail.



to a great depth inwards perpendicularly to the surface, while in Fig. 13, representing a section of new process rail, a similar seam has been squeezed out to an almost horizontal position. At the same time the grain structure is rendered much finer.

Conclusions. There can be no doubt that the Bartscherer process thoroughly justifies itself in practice, and ought to be universally adopted by all rail-rolling undertakings. This statement is not based on our own experience alone, but appears to be supported by that of others. In a paper read at the IV. International Rail Congress, for instance, it was stated that there was not a single impact test failure when 25,000 tons of new process rails were tested, whereas previously rejections on that score were 2%.

EXPERIMENTS on SELF-LOCKING DIFFERENTIAL GEARS for VEHICLES

By FRITZ G. ALTMANN and GEORG HEIMANN. (From *Zeitschrift des VDI*, Vol. 85, Nos. 35-36, September, 1941, pp. 749-754).

AN inherent characteristic, an undesirable one, of bevel differential gears, is that their efficiency of operation depends upon the adhesion existing between the road surface and wheels. An efficient solution of the whole problem is urgently required, considering the vast quantity of mechanical transport which is being employed in modern warfare and which has to cover thousands of miles on third class roads and sometimes over trackless country. The adhesion between wheel and ground is most irregular, in such instances, as would be expected, and often one of the driving wheels is lifted clear of the ground.

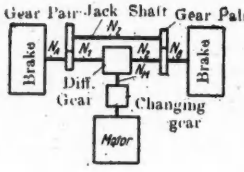


Fig. 1

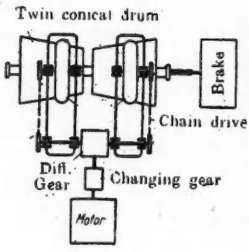


Fig. 2

Therefore, it was natural that much work was expended in an endeavour to design a better differential gear which would prevent "over-running" of the wheels. Among the many designs, two deserve careful consideration, namely the worm gear and the oscillating roller type.

The locking value and the behaviour of the differential gear when taking a curve determines the efficacy of the design. By locking value is understood that maximum ratio of turning moments transmitted to the two driving wheel shafts at which the gear is still locking, i.e., over-running of a wheel does not yet occur. Accordingly, the locking value of a non-locking gear, say a bevel gear, becomes 1.

In order to determine the locking value and behaviour of differential gears, a testing apparatus had to be designed, such that conditions similar to those met in reality could be arranged. The general layout and arrangement of the testing apparatus is shown in Figs. 1 and 2. As can be seen, the power of the driving motor is taken up by two brakes. An intermediate or jack shaft with two gear wheels of different size is used to impart a differential speed to the two wheels of the differential. This speed difference is carefully arranged so that it approaches conditions when taking a curve. The power distribution to the two driving wheels can be measured by estimating the torque and speed of each driving shaft. The evaluation of the locking value, on the other hand, is possible when the jack shaft is removed, by applying different loads to the two brake drums. With the design shown in Fig. 1, the gradual change over from a straight course to a turn cannot be imitated; for such purposes the design Fig. 2 is called upon. Here the simple

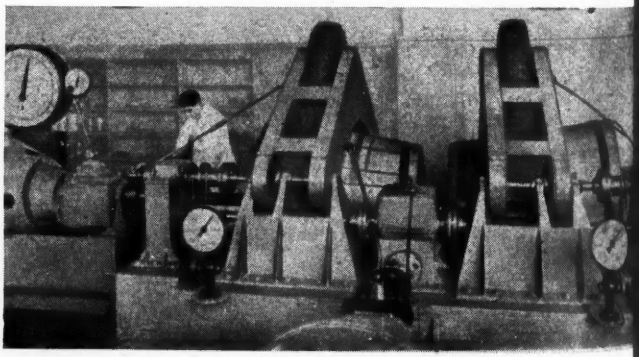


Fig. 3

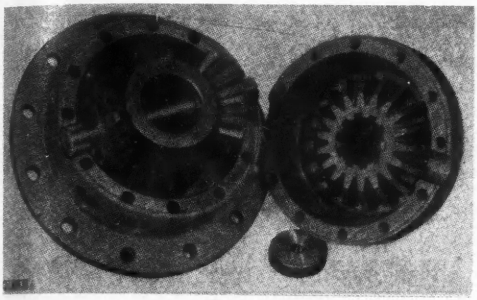


Fig. 4

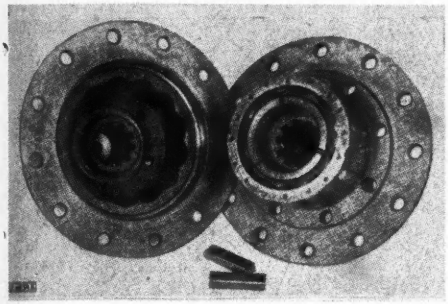


Fig. 5

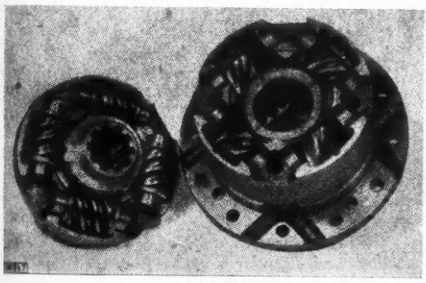


Fig. 6

fixed speed shaft is replaced by a variable speed cone drive, mounted on the same shaft (Fig. 3).

The evaluation of the locking value of the three types of gears (shown in Figs. 4, 5 and 6, and in the following briefly called type 1, 2, or 3 respectively) was affected. After the jack shaft has been disengaged a small load is applied on one of the brakes, corresponding to the adhesion of ground in reality. The load on the second brake is then gradually increased until a differential speed is indicated on the tachometers attached to the two driving shafts. The ratio of the load readings on the brakes is now the locking value of the differential gear.

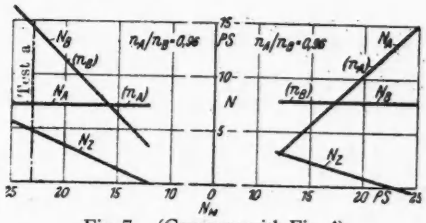


Fig. 7. (Compare with Fig. 4)

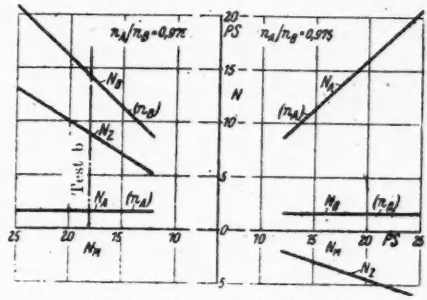


Fig. 8. (Compare with Fig. 5)

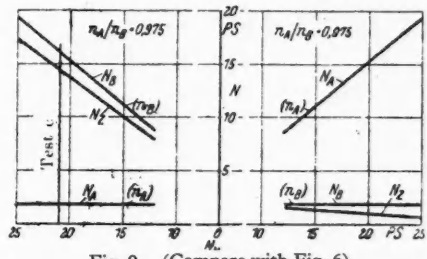


Fig. 9. (Compare with Fig. 6)

The experiments have shown that the locking value of type 1 gear is indeed 1, if the small frictional losses in the gear are neglected. Type 2 locking gear was found to have a locking value between 5 and 2, the larger figure occurring at the beginning of the test, while after a longer run, this value falls off to about 2. For operation over a longer distance, therefore, the value 2 must be taken as characteristic to this type of differential gear. Finally type 3 gear disclosed a locking value of about 46 to 18, according to the value of pitch angle of the worm wheel.

Behaviour of Differential Gears when "Taking a Curve."

During the test the following readings were taken: (See Fig. 1).

(1) N_M = The power transmitted from motor to differential gear.

(2) The power taken up by the brakes, N_A and N_B respectively.

(3) The power transmitted by the jack shaft, N_Z.

The Value of N_Z was determined, in a series of experiments, independently of N_A and N_B respectively, with increasing values of N_M. Typical curves for the results are shown in Figs. 7-9. In the left half shaft N_A is kept constant, in the right half shaft N_B. A notable feature revealed by the graph is that N_Z does not become zero when $N_A = N_B$. This is because the powers transmitted to the driving shafts during a turn are in the ratio of the speeds of the two wheels (with Type 1 gear). Therefore, there will be power $N_D = N_1 - N_A$ transmitted by the jack shaft. In addition, a small power (N_K) is transmitted continuously in the chain made up by the jack shaft, the differential gear, and the two gear pairs. So that the total power transmitted by the jack shaft, N_Z, is equal to $N_D + N_K = N_K + N_1 - N_A$. The actual magnitude of N_Z depends upon the load applied to the two brakes.

Power Distribution during the Tests.

With Type 1 gear, the turning moment transmitted to the two driving shafts is the same, though the speed of the wheels may be different. From this it follows that the power N_1 and N_2 must be in the ratio of the speeds, i.e., $n_1/n_2 = 1/i$. Also the sum of the power to the two driving axles $N_A + N_B$ is equal to $\eta (N_1 + N_2)$, where η is the mechanical efficiency of the apparatus. Hence,

$$N_1 = \frac{N_A + N_B}{\eta (1 + i)} \quad \ldots \quad \ldots \quad (1)$$

If now $N_1 > N_A$, then part of the power will be transmitted through the intermediate shaft to the other brake, that is, $N_D = N_1 - N_A$. But $N_Z = N_D + N_K$, where N_K is a cyclic power as mentioned before, we have

$$N_Z = \frac{N_A + N_B}{\eta (1 + i)} - N_A + N_K \quad \ldots \quad (2)$$

In this equation all the quantities are known or can be determined except N_K, hence it can be solved for N_K. Now Fig. 10 can be drawn, which represents the power distribution during the test. Various losses in the mechanism (bearings, transmission, etc.), are represented by the letters a, b, c, d, etc., and are shown as small branches.

The case is different with locking differential gears. Here, namely, the driving axles transmit different torques, and consequently the ratio N_2/N_1 is not equal to i, but has a different value, say q. By substituting q in place of i we now get:

$$N_Z = \frac{N_A + N_B}{\eta (1 + q)} - N_A + N_K \quad \ldots \quad (3)$$

In this equation there are two unknown quantities, N_K and q. But as also in this case the value of q depends only upon the design of the gear and not on the output of the motor, by carrying out two sets of tests with different loads on the brake we get:

$$\frac{N_{A1} + N_{B1}}{N_{A1} + N_{Z1} - N_{K1}} = \frac{N_{A2} + N_{B2}}{N_{A2} + N_{Z2} - N_{K2}} \quad \ldots \quad (4)$$

In this equation the only unknowns are N_{K1} and N_{K2}, but if the two sets of experiments are arranged so that N_{M1} and N_{M2} are very close to one another, then we can safely assume that $N_{K1} = N_{K2}$, and hence by re-arranging the equation and putting $N_K = N_{K1} = N_{K2}$, we get:

$$N_K = \frac{(N_{A1} + N_{B1})(N_{A2} + N_{Z2}) - (N_{A2} + N_{B2})(N_{A1} + N_{Z1})}{(N_{A1} + N_{B1}) - (N_{A2} + N_{B2})} \quad (5)$$

Having found the value of N_K, the value of q can be calculated from equation 3. The flow of power in locking gears can now be drawn similarly to that of the level gear, and is shown in Figs. 11 and 12. To enable an easy comparison between the various gears, the figures were so drawn that N_M was the same in each case. From the Figs. 10, 11 and 12 the following conclusions can be drawn.

Type 1 gear shows during a curve, provided the adhesion is equally as good for both wheels, a power distribution corresponding to the speeds of the two wheels. The stresses in the testing apparatus produce a loss of power the magnitude of which depends upon the total power of the

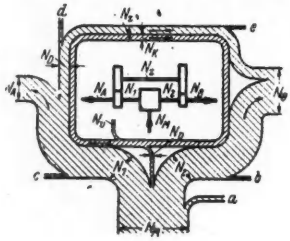


Fig. 10

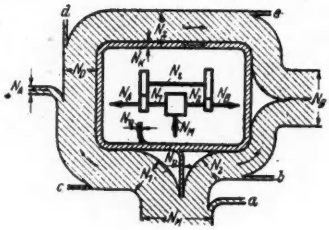


Fig. 11

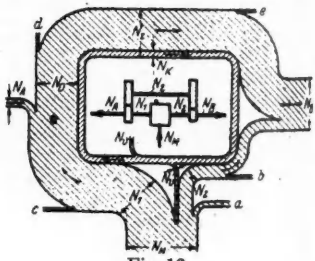


Fig. 12

motor, and is in the neighbourhood of 8% of the total power.

Type 2 gear under similar conditions provides a power distribution differing from the speed ratio of the wheels, and which depends upon the differential radii of the sliding path of the oscillating rollers.

Finally, the gear, type 3, divides the power under the same conditions so that the greater portion goes to the wheel rotating at lower speed. The faster wheel is consequently loaded to a lesser extent, and receives about 10 to 25% of the total available power, depending upon the radius of curvature of the path.

Having determined the behaviour of the gears on the test bench, estimations of their behaviour under actual working conditions were made. For this purpose Fig. 13 was drawn, in which the power distribution of the various gears is shown under different conditions of operation. The width of the rising branch of the power flow represents the motor output while the distribution is represented in a similar manner by the two branches on the horizontal direction. The vertically ascending narrow branch represents the power loss when N_1/N_2 is not equal to n_1/n_2.

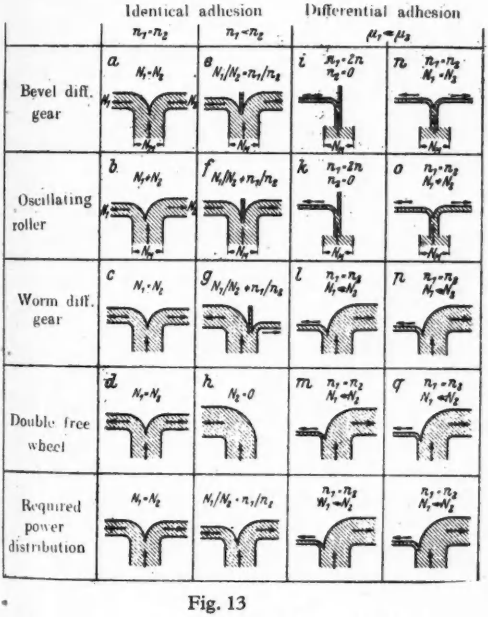


Fig. 13

Motion in a straight line with equal adhesion of the two wheels (Column 1, Fig. 13). In this case $n_1=n_2$, and there is no difference between gears Type 1, Type 3, or the free wheel (for comparison's sake the behaviour of the free wheel type gear is also included in Fig. 13). Type 2 gear on the other hand differs as N_1 is not equal to N_2; in this case, the power to the two wheels correspond to the difference of radii of the sliding paths.

Circular motion with equal adhesion of the two wheels (Column 2, Fig. 13). The speed of one wheel, n_1, is less than the speed of the other, n_2. Although Type 1 and 2 do not behave in the same manner, there is only a very slight difference between the power distribution of these gears. Type 3 gear transmits about 90% of the power to the wheel of smaller speed, the actual value depending upon the radius of curvature of the curved path. The free wheel transmits all of the available power to the wheel of smaller speed, the fast running one being disengaged.

Starting from rest with different adhesion of the two wheels (Column 3, Fig. 13). Here it is assumed that μ_1 is much smaller than μ_2; the adhesion of one of the wheels is so small that only a small fraction of the available power can be utilized by this wheel.

If a vehicle, fitted with type 1 gear, is started under such circumstances, then the wheel with small adhesion to the ground will slip. But as with this type of gear the turning moment to both wheel axles is the same, the vehicle will remain stationary as one of the wheels will be rotating at twice the differential gear speed.

Slightly different is the case with gear, type 2; the wheel with the greater adhesion receives a greater portion of the power, but as the locking value of the gear is very small, in effect the vehicle will not start moving in most cases. The power driving the vehicle forward will prove insufficient.

The much greater locking value of gear type 3, will provide such a power distribution, that will set the car into motion.

Similar is the case with the free wheel, but with the difference that the locking value being infinitely large, and, therefore, it is a certainty that the vehicle can be started under such conditions.

Forward motion with different adhesion of the two wheels (Column 4, Fig. 13). Consider the case when the vehicle is moving along a straight path, and one of the wheels runs over ice, or frozen earth (small adhesion), while the other is still running on soft ground (good adhesion). With type 1 gear, remembering that the turning moment to both wheel axles is the same, the power will suddenly fall off, the turning

moment becoming small. Acceleration or continuation of the motion up a gradient becomes impossible owing to slip of one of the wheels.

The small locking value of type 2 gear proves inadequate for acceleration up a gradient.

Type 3 gear and the free wheel on the other hand, can transmit sufficient power to the wheel running on soft ground to allow continuation of the motion or for acceleration. As can be seen from Fig. 13, the whole of the power is still being utilized, even under such conditions.

Summarizing the results, the following general conclusions can be drawn. Type 1 gear provides an adequate power distribution for uninterrupted motion of the vehicle only if the adhesion is equally good of both wheels. If this is not the case, one of the wheels over-runs; almost the same could be said about gear type 2.

With the free wheel there is no power distribution at all, except when running along a straight course. Otherwise the fast running wheel is disengaged, and as this occurs abruptly, fracturing of the shaft might be the result.

By far the most satisfactory result is shown by the worm gear type of differential gear. Owing to its high locking value, it is possible to transmit sufficient torque to the wheel that is still in contact with the ground.

OIL SEPARATORS FOR STEAM ENGINES

By ING. A. H. W. HELLEMANS. (From *Brennstoff und Wärmewirtschaft*, Vol. 23, No. 11, 1941, pp. 172-178).

DURING the past few years forced circulation boilers are rapidly gaining ground for industrial purposes. This boiler design, however, demands a pure and oil free feed water supply, and this is one reason why surface condensers are employed; these permit the utilisation of the condensate for feed, so that only a small amount of make-up feed water, which is lost by evaporation, etc., needs to be drawn from the feed tank or hot well after thorough cleansing.

By adopting this method, the use of oil separators becomes imperative. Oil separators are used for separating out the oil from the exhaust steam (at least, the bulk of it) and the condensate can then be further filtered and returned to the boiler.

Apart from this consideration, the fullest use of oil separators is also supported by the present shortage of raw materials (also lubricants), which forces every plant to the highest possible utilisation of the available supplies of oil or fuel. Oil separators are great assets to this end, as they are able to recover about 60 to 70% of the oil from the exhaust steam.

The oil separators can be grouped into the following two types.

(1) **Centrifugal type.** The principle of operation of this type of separator is based upon the fact that the bulk of the lubricant is carried by the steam in a state of suspension, i.e., in the form of small globules so that the density of the lubricant is far greater than that of the steam. Consequently if the exhaust steam, carrying the lubricant, is passed through a spiral-shaped chamber, the oil particles will be thrown out by centrifugal force, while the steam continues along its path. Fig. 1 shows the basic design of a centrifugal separator. The spiral internal pipe is surrounded by a perforated cylinder, through which the oil is thrown by centrifugal force, and which prevents the oil from re-entering the steam flow. The oil thus separated is collected at the bottom of the separator. Newer designs are somewhat modified, in that the angle of the helix of the spiral decreases towards the end of the separator to increase the efficiency of separation. Further, precautions are taken to prevent the oil from re-entering the steam flow owing to turbulence or suction. The separators are usually of the horizontal type, a typical one being shown in Fig. 2.

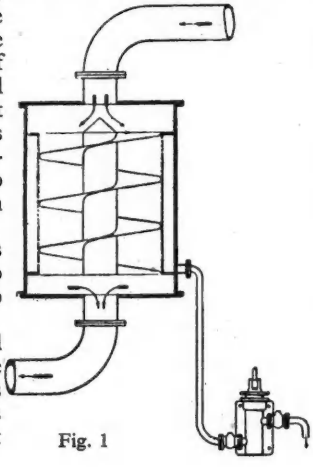


Fig. 1

Considerable improvement can be achieved by employing an impeller of some sort to impress a spiral motion upon the steam/oil mixture. The collection of the oil can also be improved by making the casing of conical shape. The impeller should be driven at constant speed for

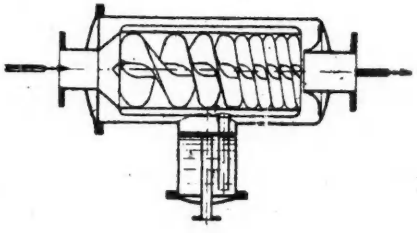


Fig. 2

good efficiency, and, therefore, the exhaust steam cannot be utilised for this purpose as this would cause variation of speed with the load on the prime mover.

(2) **Impact type.** If the steam/oil mixture impinges upon an obstacle placed in the path of the steam flow, then the heavier constituent, namely, the oil, will be released from its state of suspension, and by a suitable arrangement can be collected. Impact type of separators are based on this principle. The separator consists essentially of an enlarged section of the pipe, into which rows of vertical bars, of various shape, are placed. The cross section of these bars varies with almost every design and, indeed, a great variety is disclosed by various makes of separators. Figs. 3 and 4 show some typical separators, the first mentioned being fitted with V bars, the latter with alternating rows of V and U-shaped bars. As the steam passes through the separator it impinges against these bars and the oil then flows down the bars and is collected and removed from the bottom. Again, other manufacturers use perforated grids in place of the bars, the shapes of the perforations being as numerous as the cross sections of the bars.

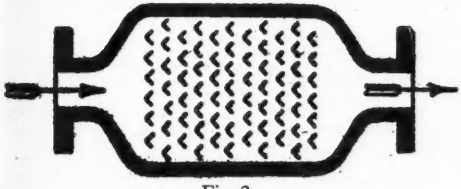


Fig. 3

Considering the centrifugal type of separator the principal equation governing their efficiency is given by $C = \frac{m \cdot v^2}{r}$, where C is the centrifugal force impressed upon the oil and steam particles, m is the mass of the particles, v the velocity, and r the radius of curvature of the spiral tube. It is clear that with identical velocity and radius, r, of the steam and oil particles, the centrifugal force impressed upon them will be in the ratio of their respective masses. The specific weight of steam (1 m^3) at 0.1 atm. pressure is 0.067 kg, and that of oil (actually water and oil) about 1000 kg and, therefore, the centrifugal force acting upon the oil is 15,000 times as large as that acting upon the steam particles. According to this the efficiency of separation should decrease with increasing steam pressure; as an example, at 3 atm. pressure the sp. weight of steam would be 1622 kg and, therefore, the forces acting upon oil and steam are in the ratio 600:1 only. Practice has shown, however, that increasing steam pressure does not bring about a fall of efficiency of separation, on the contrary still better results are obtained. Therefore, it must be concluded that many other factors, too,

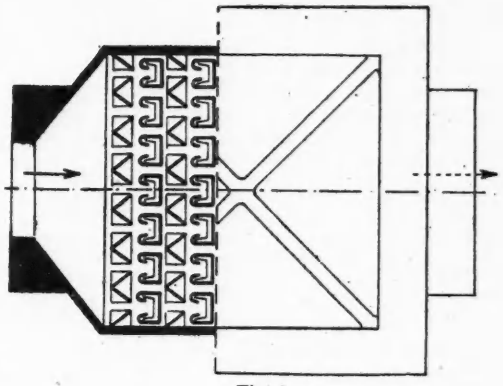


Fig. 4

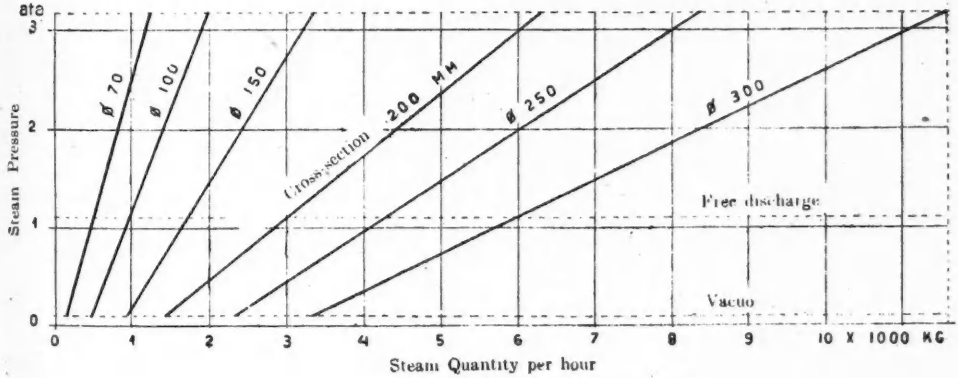


Fig. 5

will have a marked effect upon the efficiency of separation.

For the impact type separator, Fig. 5 gives some information regarding the quantity of steam that can be dealt with by separators of various cross-section in dependence on steam pressure. The resistance of the separator is negligible, therefore, if a separator proves to be of insufficient efficiency, it need not be removed, but another separator may be included in the system.

In general it can be said of this type of separator that the shape or cross-section of the impact element is of very little importance. This fact is very well illustrated by the various shapes and designs manufactured, which all operate with about the same efficiency. Some improvement can only be achieved by circulating cold water in the first row of impact bars so as to promote condensation and hence separation of oil.

Although, as can be seen from the foregoing, the separator is a very simple apparatus in itself, the efficiency of separation is affected by other factors as well, amongst which the most important are :

(1) The condition of steam,

(2) The class of oil used as lubricant.

To 1. Practice has proved, against theory, that separation is more efficient when the steam pressure is higher and the dryness factor lower. This is because if the oil particles exist as separate globules in suspension in the steam, they will readily separate out, but not so if the steam molecules are surrounded by an oil film, that is oil and steam form an emulsion. If this happens to be the case it is necessary to inject into the steam some of the condensate in order to promote condensation. Usually the exhaust steam is not superheated, but at any rate it is sound practice to locate the separator as far as possible from the steam engine, to allow cooling and condensation during its path from engine to separator.

To 2. The ignition temperature of the lubricant should be lower than the steam temperature. If the latter is very high, some of the oil will evaporate and forms an emulsion with the steam, which inhibits separation. Lower steam temperature, on the other hand, is not always permissible, as this would increase the steam consumption of the engine. With regard to oil recovery it is, therefore, better practice to utilise the cylinder surfaces for lubrication, and not to introduce the lubricant in an atomized condition into the cylinder. This results in reduction of oil evaporation as generally it will be exposed to lower temperatures.

Mineral oils should be given preference over vegetable oils, but even so the grade will be an important factor. Experiments on 4 different grades of lubricant (mineral) have shown that although their analysis revealed very similar properties, their behaviour, regarding separability, differed considerably. On the other hand it was found that a higher ignition temperature of the oil reduces evaporation and promotes separation.

It was also found that some grades of mineral oil, otherwise suitable for lubrication purposes, formed emulsions with the steam making separation, and thus recovery impracticable. No satisfactory explanation can be given to this phenomenon.

In general it is quite safe to expect that all oil particles of 0.005 mm. diam. and a large proportion of those of 2-5/1000 mm. diam. will be separated out by using an oil separator of some sort. The efficiency of these is usually high, but apart from the design, other factors, too, should be considered as affecting the operation.

STORAGE OF SUMMER SURPLUS ENERGY FOR CENTRAL HEATING IN WINTER TIME

(From a reprint of *Elektrizitätswirtschaft*, 1941, No. 27, p. 426 in *Bulletin Association Suisse des Electriciens*, Vol. XXXII., No. 24, December 3rd, 1941, p. 676).

SOME time ago the Swiss, P. Seehaus, published a study proposing the storage of summer surplus energy of the Swiss water powers in huge insulated hot water accumulators. Now consulting Engineer, Per V. Brüel, a collaborator of Professor P. O. Pedersen, has made a similar proposal, published in a Danish technical paper. According to his project wind motors should be used as generators of the energy for the heating of residences. Whereas in Switzerland only during summer time surplus energy is available, in Denmark the wind can be utilized more or less during the whole year. The energy stored during the four or five months of summer time can be used as a stand-by source of heat. The hot water accumulators, which have to be provided in Denmark, are therefore small in comparison with those of the Swiss project. Brüel found that an accumulator with a content of 1500 m^3 (depth 7m, diameter 16.5 m) will be sufficient for a building

*See the abstract in THE ENGINEERS' DIGEST, Vol. 2, No. 2, 1941, February, p. 56.

containing 30 lodgings comprising two rooms each. The maximum temperature of the water attained at the end of the summer would amount to 95° C. approximately. It would decrease during the winter to 50 to 60° C., which temperature is quite appropriate for a normal central heating plant. A good insulation of the accumulator is of greatest importance of course. It is intended to use powdered peat for this purpose.

The cost of such a heating plant would amount to 35,000 Danish crowns for the accumulator and to 25,000 crowns for the wind power plant. Investment costs as well as expenses for the attendance of a boiler will be economised with such wind motor and accumulator plants.

ELECTRIC SUPPLY FOR FUTURE GERMAN RESIDENCE BUILDINGS

(From *Bulletin Association Suisse des Electriciens*, Vol. XXXII., No. 18, September 10th, 1941, p. 438/41. Abstract of a paper by H. LAURICK. *Elektrotechnische Zeitschrift* (*ETZ*), Vol. 62, No. 25, 1941, p. 569).

IT is expected that within the next twenty years there will be a need for 6 million new residences in Germany, 300,000 of which should be available within the first year after the war. It is intended to build blocks of flats as well as small privately owned houses and settlements. 80% of the residences will comprise 4 rooms, 10% 5 rooms and 10% 3 rooms. A lodging with 4 rooms will consist of:

1.	Combined kitchen and sitting room	265	sq. feet
2.	Large bed room	175	,,
3.	Two small bed rooms	220	,,
4.	Shower bath and W.C.	55	,,
5.	Entrance hall	65	,,
6.	Balcony	35	,,
		810	sq. feet

Supply system. Electric energy is to be supplied to all lodgings for lighting, for the radio and for small motors. The use of gas is provided only where conditions are exceptionally favourable. Electric cookers will generally be installed, as electric cooking will be economical in regard to the mean price of 4 Pfennig/kWh (½d). Furthermore, gas would not be desirable in kitchen-sitting rooms. A two-part tariff will be used throughout, comprising a flat charge and additional payment for the kWhs consumed.

Method of distribution.—Wherever possible three-phase current, 3×220/380 V, is to be used. Transformers are to be so located, that short distribution lines result. Cross connections between the feeders are recommended for branched networks, especially in cases of cable networks. It is assumed that the requirements of a residence will amount to 125 W for light, 200 W for water heating and 400 W for cooking. The decision between overhead line and cable distribution depends rather on the cost of maintenance and renewal than on the cost of first installation. For a district with low density of load the distribution by overhead lines, for a district of high density the distribution by cables is more economical (Fig. 1). In general distribution by cable network will be used for blocks of flats and overhead lines for the supply of houses of only one story.

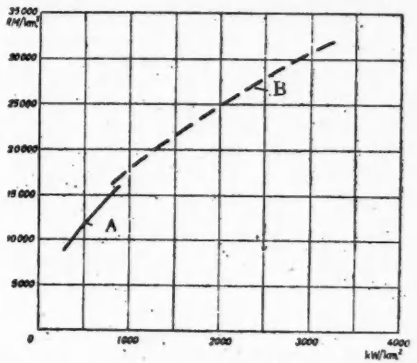


Fig. 1. Relation between the density of load and the yearly expenses for overhead line distribution (A), and cable networks (B).

In streets with blocks of flats cables will be run in the pavement on both sides, if the load is high. For small loads one cable with connections crossing the street will be sufficient. Each cross-connection may be used for the supply of two adjoining houses.

Overhead lines are generally erected only on one side of the street, but on both sides in main streets in order to eliminate a large number of crossings. The maintenance costs of wooden poles is not very high. The poles can be used for fixing the street lamp fittings. Placing the overhead lines in the rear of the houses would be more agreeable, of course, but then cheap installment of the street lighting would become impossible. Lines fastened to roof supports would be less conspicuous, but not so accessible. Only occasionally will an arrangement of the lines on wall bracket supports be used, as it is of unsightly appearance and can only be utilized, where no possibility exists of touching the conductors from any accessible point (Fig. 2).

Fig. 2. Distribution line on wall bracket supports.

Service connection. Instead of expensive cast iron entrance boxes for cables or sheet iron boxes for the entrance of overhead lines, boxes from plastics are now available, which have the further great advantage of not becoming conductors in case of failures.

The cable entrance boxes (Fig. 3) contain in the lower part, which can be sealed by the supply company, delayed action fuses which do not fuse in cases of short overloads. In small houses with only one tenant the entrance box may be combined with the meter panel as shown in Fig. 3, the upper part of which is used for fixing the main fuses, which are accessible to the consumer.

Main distribution board. Great buildings have a main distribution board, from which the rising mains and the circuits for the lighting of the staircase, the cellar and the loft start, as well as the circuits for the wash-room and the air raid shelter. Each circuit is protected by a fuse corresponding to its cross-section. It is recommended not to use automatic cut-outs in place of fuses, as heavy short circuits may occur at the main board, which surpass the breaking capacity of such switches. For the rising mains in dwelling houses delayed action fuses should be provided.

Main circuits and rising mains. The drop of voltage in the main distributing lines of blocks of flats should not exceed 0.5% ; but as this may become sometimes impossible the Berlin Electricity Works permit a drop of voltage up to 1.5% between the entrance box of the house and the meters.

Two tables are given containing the cross sections recommended for the rising mains. There is only the use of aluminium wires taken into consideration for this purpose. One of these tables covers houses, in which electric cookers and water heaters up to 2 kW are installed, a second table deals with installations comprising water heaters of 3 to 6 kW. Cross sections of the main distribution circuits for 220 V d.c. or a.c. two wires, 2×220 V d.c. three wires, 3×220/380 V a.c. four wires and 3×220 V a.c. three wires are given in these tables. The values recommended for 3×220/380 V a.c. are contained in Table I., which is a combination of figures of the two original tables.

TABLE I.

Cross section (mm²) of aluminium wires for the rising mains of three phase 3 × 220/380 V (four wires) distributions.

	Number of lodgings supplied.						
For lodgings containing	2	4	6	8	10	12	
Cookers and water heaters up to 2 kW	16	16	16	25	25		Max. distance betw. entrance box and mid point of rising mains 55 yards
Cookers and water heaters of 3 to 6 kW	Number of lodgings supplied						
	10	16	16	35	35	35	
	3 phases			one phase			

In buildings with only a few lodgings, each lodging is connected to the three phases. In buildings with a great number of lodgings it is regarded advisable to provide the connexion of each lodging to only one phase, achieving the balance of the load on the three phases by a suitable repartition. If bath and kitchen have separate water heaters, they should be connected to a change-over switch, as simultaneous use has to be prevented.

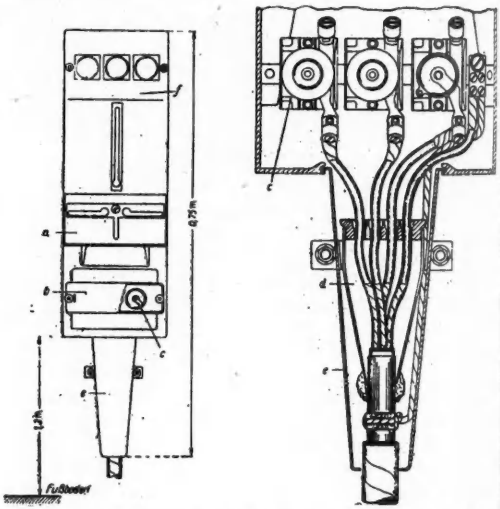


Fig. 3. Entrance box, main fuses, and meter panel for a small house with only one tenant ; (a) meter panel ; (b) cover for the main fuses, sealed by the supply company ; (c) Fuses ; (d) Cable and box ; (e) Cover for this box ; (f) Cover of the main fuses of the installation. Fussboden = Floor.

In the cellar the main circuits are to be laid in insulated conduits fixed by conduit wall clips at a certain distance from the walls. The rising mains in the stair-cases are laid under the plaster in insulated conduits (*) or rubber tubes.

A junction box is to be provided in each floor. It is expected that according to new regulations to be issued shortly it will be permissible to use, for the connexion to the meter, the cross section next in size to that of the mains without inserting fuses. For general use a cross section of 16mm² aluminium wire is considered as sufficient.

Meters, meter-panels and distribution. It is not recommended to centralize the meters in the cellar; they should be installed within each flat in a recess provided for this purpose. The necessity is stressed to agree on a standard meter-panel, on to which the meter can easily be fixed. The 10 Amp. meter will generally be suitable, as it may carry overloads up to 30 Amp. The fuses for the different circuits are placed next to the meter. Automatic switches would be welcome, but in most cases they will be too expensive. Three circuits are to be provided, one for the light, one for the cooker and one for the water heater. For the wiring for the light 2.5 mm² aluminium wire will be used.

Lighting installation.

In a normal four-room residence the following points and plug sockets are to be provided:

KITCHEN-SITTING ROOM:
1 ceiling point, switch next to the door.
1 point for the cooker, switch close to it.
3 plug sockets.

BEDROOM FOR THE PARENTS:
1 ceiling point, change-over switch next to the door and cord-switch at the bed.
1 double plug socket over the night-stand.

BEDROOM FOR THE CHILDREN:
1 ceiling point, switch next to the door.
1 plug socket next to the door.

SHOWER BATH:
1 ceiling point over the washing basin, switch next to the door.

ENTRANCE:
1 ceiling point with switch.

BALCONY: 1 plug socket.

All installation is to be laid under the plaster, in insulated conduits or rubber tubes, or conduit wires are to be used. A new type of wire will be available in future. It will consist of two or three rubber insulated cores connected by one or two stems. The whole system will be covered with a layer of reclaimed rubber. This type of wire will be fixed on the first rough cast or within the hollow space of the ceiling by means of steel nails driven through the stem between the wires. Experimental installations have shown a high insulation resistance after several years of use. It is a disadvantage of this type of wire, that replacement is impossible. The wires are covered without any further protection by the plastering of the walls. So the expensive cutting of chases or grooves for putting in the wiring is avoided.

Water heater and cooker installation. For the cooker 2×6 mm² aluminium wire is used laid in insulated conduits or rubber tubes under the plaster. The wires may be connected to the cooker without using a special plug contact. Suitable arrangements for such connexions are shown in two figures. The connexions of the water heaters may be made in a similar way. For the refrigerator a plug socket with a connexion to the neutral or with an earthing contact should be used.

General installation of the houses. This installation includes the illumination of the staircases, of the cellar, the loft, the wash room and

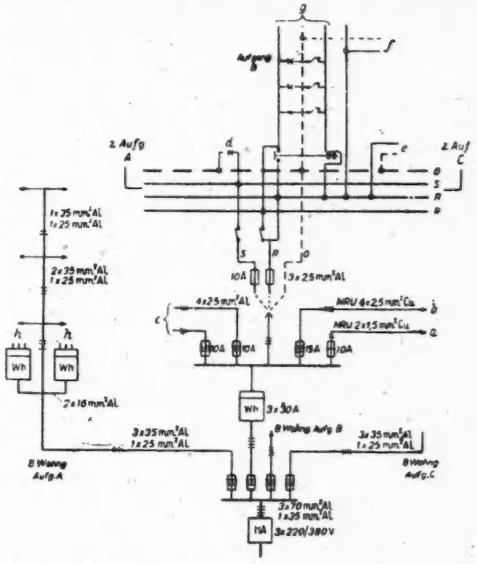


Fig. 4. Installation for a block of flats with three staircases (A, B, and C), each comprising 8 flats. (a) Lighting circuit for the wash room, for the motors of the wash machine, and for the centrifugal machine; (b) Circuit for the heater of the wash machine 6kW, and the ironing machine 3kW; (c) Circuit for the air-raid shelter: 12 plug sockets for 10 fires, each 1kW, and two cooking appliances; (d) Circuit for the illumination of the number of the house; (e) Circuit for the cellar; (f) Circuit for the loft; (g) Circuit for lighting the staircases; (h) Circuit for a flat: light, cooker 5kW, water heater 5kW.

(*) German insulated conduits are paper conduits with a metal sheath of brass or lead-coated iron; the latter design is more generally used. The insulation resistance of the wires laid in these conduits has to be such, that it is sufficient, when the insulation of the paper tube of the conduit is supposed to be zero.

the air raid shelter. The distribution in a large flat house is shown in Fig. 4.

In general a washing machine is too expensive to be installed in small houses. For large houses the cost of the installation of such a machine in the communal wash-room is of minor importance. A motor driven rolling press and some kind of drying plant will be added. For the wiring in the wash-room lead sheathed wires have to be used. It is recommended to use copper for these wires instead of aluminium.

The air raid shelter is equipped with a suitable lighting installation and with plug sockets for heating and cooking appliances.

Large buildings will have an installation for the wireless with a common aerial. If the installation comprises more than five outlets (plug sockets for the connexion of the wireless apparatus) an amplifier will be provided. The connexions of the outlets with the aerial are to be bedded into insulated conduits or rubber tubes.

CHARACTERISTICS OF LOW VOLTAGE FLUORESCENT LAMPS AT HIGH FREQUENCIES

By R. F. HAYS, Westinghouse Lamp Division. (From *Illuminating Engineering, N.Y.*, Vol. XXXVI., No. 5, May, 1941, pp. 570/76. The author has published another Article dealing with the same matter in Electrical Engineering, Vol. 60, November, 1941, p. 539).

THE recent tendency to equip transport planes with high frequency power supplies has made possible decided reductions in the size and weight of fluorescent lamps auxiliaries, the use of this type of lamp being attractive because of their high efficiency, the tubular shape of the lamps and the color obtained. An investigation has been made to determine the characteristics of such lamps at higher frequencies, particularly in the neighbourhood of 400 cycles, which is the tentative standard for aeroplanes.

Theory.—It is well-known that a certain amount of time is necessary for ionization to build up in a gas through which an electric current is passed, that the iron and electron densities are a function of current, and that time is necessary for the gas to deionize. The more intense the ionization in a vapor lamp, the smaller is the voltage necessary to strike an arc between the electrodes. Near the end of each half cycle of current at a frequency of 60 cycles the gas in a fluorescent lamp deionizes to such an extent that a relatively high voltage is necessary to re-establish the arc. This is shown by the curves for current and voltage in a fluorescent lamp at a frequency of 60 cycles (Fig. 1A). At a frequency as high as 400 or 500 cycles the ionization density is unable to follow the variations in current closely and its value remains more nearly constant, with the result that a high peak voltage is not necessary to re-establish the arc each half cycle as shown in Fig. 1B. Evidence substantiating this theory is shown in the dynamic volt-ampere characteristics Fig. 2. The lamps behave at high frequencies more like a resistance.

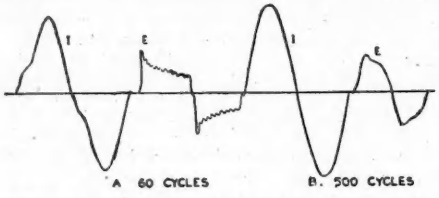


Fig. 1. Lamp current and voltage in a fluorescent lamp.

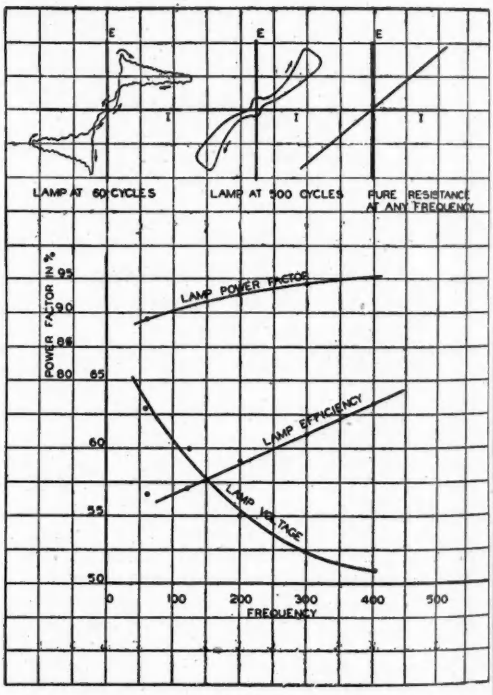


Fig. 2 (top) Dynamic Volt-Ampere characteristics.
Fig. 3 (bottom) Effect of frequency upon lamp power factor, efficiency and voltage.

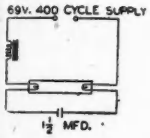


Fig. 4. Resonant circuit of operation of lamp at 400 cycles.

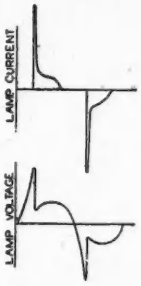
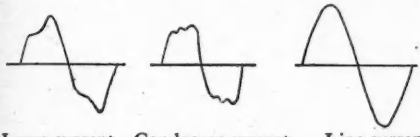


Fig. 5 Lamp current and voltage wave forms for circuit similar to Fig. 4 when operated at 60 cycles.

Voltage across lamp and condenser of Fig. 4 at 400~



Lamp current Condenser current Line current
400 cycle currents for circuit shown in Fig. 4.
Fig. 6

Results.—Since at higher frequencies a fluorescent lamp behaves more like a pure resistance, voltage and current wave forms become more nearly sinusoidal and lamp power factor, which is less than unity because of non-sinusoidal wave forms, increases with frequency as shown for the 15 watt T8 fluorescent lamp in Fig. 3.

Since lamp voltage for 15 watt T8 bulb lamp at normal current is about 60 volt, the lamp may be operated from a 115-volt line once the arc is started. However, a considerable higher voltage is necessary to start the arc. Heating the electrodes to emitting temperature greatly reduces the voltage necessary to start the arc and at the same time produces a considerable improvement in lamp life by preventing positive ion bombardment of the electrodes during the starting period. Electrode heating currents great enough to produce an arc across each electrode may reduce the arc voltage necessary to establish the main discharge to a value as low as 125 volt. Both the electrode heating current and a starting voltage greater than the line voltage can be obtained by use of a circuit shown in Fig. 4. The inductance must be used as a ballast, so the condenser is the only additional equipment needed. The values of inductance and capacity must be chosen so that the current drawn by the condenser will raise the electrode temperature to the proper value, and yet the voltage across the condenser must not be high enough to start the discharge before a safe temperature of the electrodes is reached.

A resonant circuit must not be used at frequencies as low as 60 cycles. A discharge of the condenser would occur at the peak voltage when the arc is re-established. This discharge would shorten the useful life of the electrodes.

For lighting aeroplanes it is customary to use the one wire ground return system. On a three phase system, when lamp loads are balanced, the line current is only 57.8% of the value for line-to-line operation. The line to neutral voltage for a three-phase 120 volt circuit is 69 volt. Fig. 5 shows the effects of voltage variation.

Lamps start from a supply as low as 40 volt. Ordinarily a line voltage at least 1½ times lamp voltage is necessary for satisfactory operation of vapor lamps. With a resonant circuit the line voltage need not be any higher than the lamp voltage because the condenser of resonance maintains lamp voltage at the value necessary for operation. With a 120 volt supply the same inductance may be used, but the condenser need

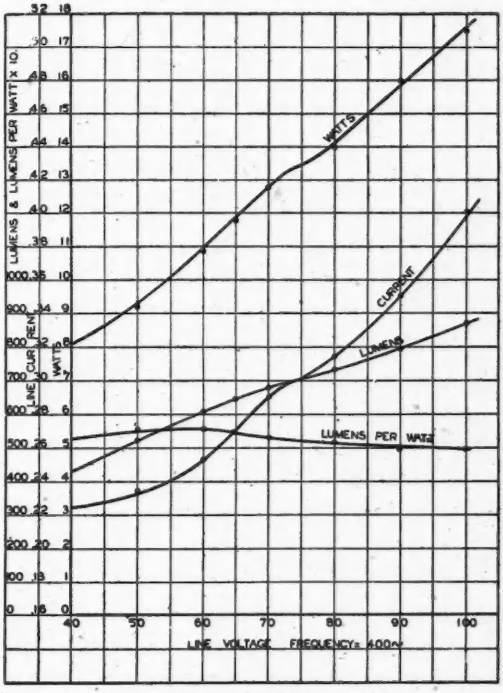


Fig. 7. Effect of voltage variation.

not be so large. Under normal operation the power lost in the inductance is approximately one watt.

Conclusions.—The modern aeroplane would seem to an ideal place for lighting with fluorescent lamps at high frequencies, because many of these planes are equipped with approximately 400 cycles 120 volt generating plants. The efficiency of fluorescent lamps at 400 cycles is approximately 20% greater than at 60 cycles and about four times as great as the efficiency of filament lamps ordinarily used in aeroplanes. At a frequency as high as 400 cycles the lamp control equipment is small and not very heavy. The use of high frequency lamps makes possible a reduction in the weight of wiring, power plant and fuel, that must be carried for operating the power plant.

For using fluorescent lamps in such places as buses and trains, where only a low voltage d.c. supply is available, an inverter or motor-generator is required for changing the low voltage d.c. into 115 volt a.c. In such cases the frequency may as well be 400 to 500 as 60 cycles, so that the auxiliaries may be smaller and the efficiency higher. There is a possibility also that for certain commercial installations the lower cost of auxiliaries, higher efficiency and reduced stroboscopic effect may justify the installation of a frequency converter to change the frequency from 25 or 60 cycles to 400 or 500 cycles.

THE EFFECT OF ARRESTS OF STRESSING UPON THE ENDURANCE STRENGTH OF FERRITIC STEELS

By HEINRICH CORNELIUS. (From *Luftfarht-Forschung*, Vol. 18, No. 8, August, 1941, pp. 285-288).

EXAMINATION of wrought iron has shown that periodical unloading and resting of a machine part subjected otherwise to a variable loading, has a considerable influence upon the working life of the material; in the case of wrought iron the effect was beneficial. Therefore, and with special regard to aircraft applications, further examinations were carried out on steels containing free ferrite. Special attention was given to the following factors during the tests:

(1) Composition of steel

(2) Amount of free ferrite, with otherwise identical structure.

(3) Shape of test piece (plain or notched).

Tables I and II give all necessary information of the steels examined. The texture of the specimens was as follows:

(1a) The bulk ferritic, the rest pearlitic.

(1b) Hardened, much less ferrite than in case 1a.

(2a and 2b) More ferrite than pearlite.

(2c) Hardened, less ferrite than in case 2a or 2b.

(3 and 4) Austenite and ferrite (ferrite: 40% and 20% respectively).

First the Wöhler curve was established for each material without interruptions, the intensity of bending stress being varied cyclically by rotating the test piece. Next, the whole process was repeated, but this time at intervals of 1/5 of the maximum number of repetitions corresponding to the previous experiment, arrests of 24 hours were introduced; the material was relieved of stress and allowed to rest at room temperature. Samples which did not fracture before the fifth rest, were then continuously tested until fracture occurred. The samples for both types of tests were taken from the same bar and tested

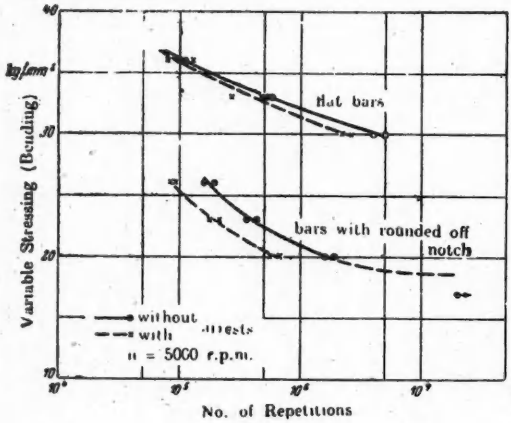


Fig. 1

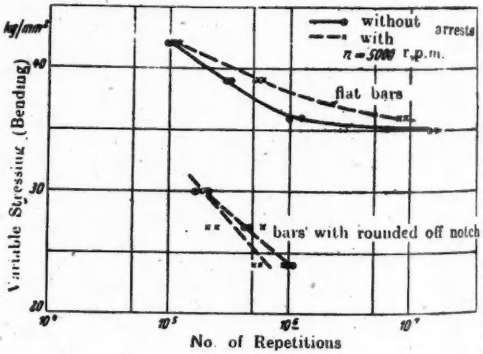


Fig. 2

on the same machine. Oil cooling was used at $20° \pm 1°$ C.

Both the plain and notched samples had an effective radius of 6 mm. Two types of notches were tested. Steels 1 and 2 had a circular notch of 0.75 mm. diameter and 0.75 mm. depth; steels 3 and 4 were provided with a V notch of 0.75 mm. depth and a vertex angle of 60 degrees. The corner was rounded off with 0.1 mm. radius. All samples were carefully finished and polished.

The result of the experiments is shown in Figs. 1 to 7. Fig. 1 and 2 refers to steels (1a) and (1b) respectively. While in the first case a reduction in the endurance test can be observed with both the plain and the notched sample (much less in the case of the plain bar), steel 1b shows a decrease only when the notched sample was tested. The effect of the rests is more marked as the limiting stress is being approached.

Figs. 3-5 refer to steels 2a, 2b and 2c respectively. The frequency of load variation was 3000, and in one case 500. The notched samples show a distinct decrease of endurance strength with steels 2a and 2b, while there is no change with steel 2c. Similarly, the plain bars show an increase of endurance strength for steels 2a and 2c, while the steel 2b is not much affected.

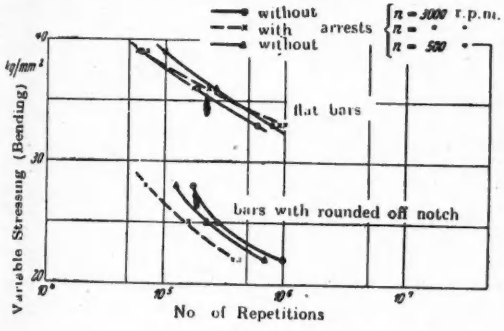


Fig. 3

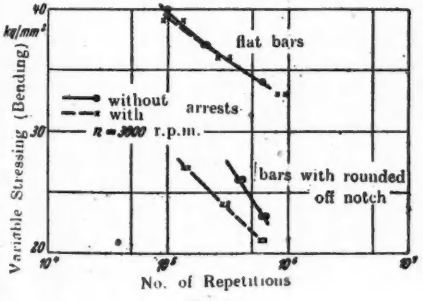


Fig. 4

Finally steels 3 and 4 were tested at a frequency of load variation, n = 2000, and as can be seen from Figs. 6 and 7, the plain bars showed a considerable improvement of endurance strength

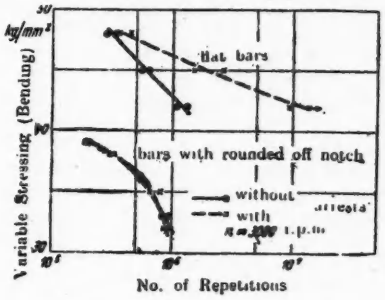


Fig. 5

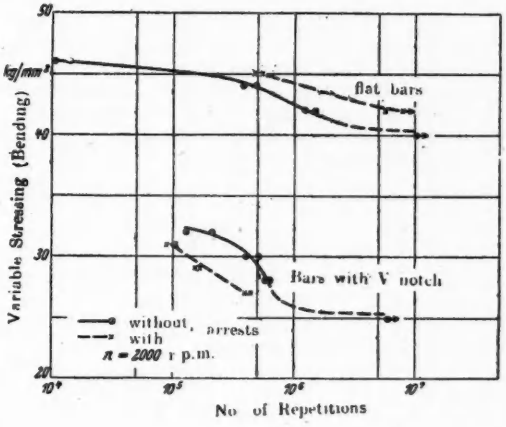


Fig. 6

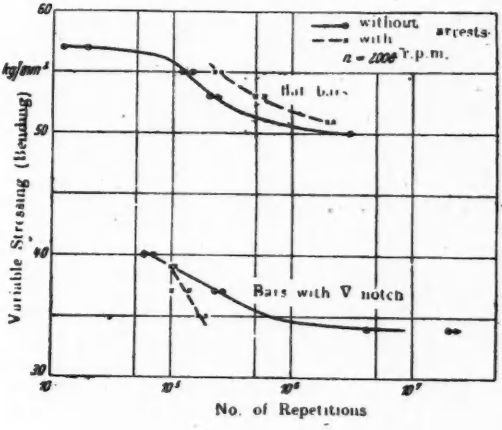


Fig. 7

with the rests, while the opposite effect takes place with the notched specimens.

It was found in general that the effect of arrests varied in many cases with the magnitude of stressing (i.e., range of stressing), and the plain bars show an improvement regarding the endurance strength when arrests are introduced at intervals. Only in one case (Fig. 1) was the opposite found. This clearly indicates that free ferrite in the material has an influence upon the endurance strength of the material, very much independently from the composition of the steel. But the quantity of free ferrite does not appear to be a measure of the improvement achieved this way. Hence it seems that apart from the ferrite content, the general texture of the steel, too, bears a relationship to the endurance strength of the steel.

The fact that just the opposite observation was made with notched samples is remarkable and difficult to explain. Out of the 7 tests, one only failed to reveal a change of endurance strength to the worse. Here, too, the effect of free ferrite is independent of the composition of the steel and appears to be somewhat more pronounced with increasing ferrite content.

As previously to this series of experiments, it was thought that ageing might be the determining factor for this behaviour, with steels 1 and 2 great care was exercised to select the specimens so that they have a different tendency to ageing. However, the tests with these steel bars failed to support this theory. So far, no satisfactory explanation can be given to this phenomenon, and it is, therefore, pertinent to give the experimental results without further comment.

TABLE I.

Steel No.	Yield Stress kg/mm²	Tenacity kg/mm²	Elongation % (l=10d)
1a	28.1	46.0	28.8
1b	39.1	62.7	13.0
2a	31.1	54.3	26.0
2b	34.3	56.4	23.5
2c	88.2	107	7.8
3	36.1	83.0	38.5
4	27.5	70.6	40.1

TABLE II.

Steel No.	Heat Treatment	Composition in %								
		C	Si	Mn	P	S	Cr	Ni	Mo	Ta+Nb
1a	880°/½ hr. air cooled	0.18	0.32	0.71	0.021	0.036	—	—	—	—
1b	810°/½ hr. water quenched .. 350°/1 hr. air cooled ..									
2a	880°/1 hr. furnace cooled ..									
2b	880°/1 hr. furnace cooled to 600°, than rapid cooling ..	0.23	0.25	0.46	0.017	0.008	1.05	—	0.19	—
2c	750°/½ hr. oil quenched .. 350°/1 hr. air cooled									
3	Quenched	0.14	0.73	8.86	—	—	18.3	0.64	—	—
4	Quenched	0.10	0.47	0.41	—	—	17.7	8.86	—	0.94

SAVING SINKING HEAD METAL

By G. G. OSTAPENKO. (*From* " *Stal*," Moscow, 1941, No. 4, pp. 24-25).

IN the Siemens-Martin shop of the Kriov Works a series of experiments was conducted to investigate the possibility of reducing the amount of metal cut away in headers when casting ingots of non-effervescing steel. The ingot mould used was as shown in Fig. 1 and the teeming was done from above, through an intermediate runner.

The sink heads or hot tops, were of two types : The " narrow " and the " wide." The former measured 410×410 mms. at the top and 540×540 mms. at the bottom ; the latter was 450×450 mms. at the top and 585×585 mms. at the bottom. The height of the sink head mould was 650 mms. throughout and the normal practice was to fill it to a level of 600, 550 or 500 mms. With equal filling levels the metal content of the wide type, therefore was greater than that of the narrow by about 4% of the total weight of the ingot.

Careful study of the macrostructure of test ingots has shown that with either type of sink head there was pronounced eccentric segregation in the upper part of the ingot and a secondary concentric region of sponginess. The latter is liable to reappear in the cross-section of the rolled

blooms and is a not infrequent cause of their rejection.

The shrinkage hole is located entirely in the upper part of the sink head (see Figs. 2 and 3) so that to remove all defective metal it is sufficient to cut away the top portion along the line (aa), provided one is prepared to overlook the less satisfactory surface of that part of the ingot which is inside the sink head.

It will be seen from the table that the shrinkage hole and its surrounding region of segregation is located 100 to 140 mms. above the base of the header if this is filled to above 500 mms. and that this applies equally to either the narrow or the wide type of head. So that even if the upper part of the sink head is not utilised, the lower part still contains a very appreciable " useful margin." With filling levels of 500 mms. and over this margin amounts to between 4 and 7% of total ingot weight.

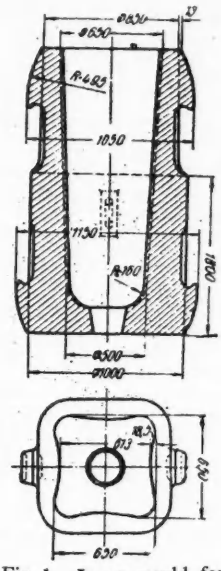
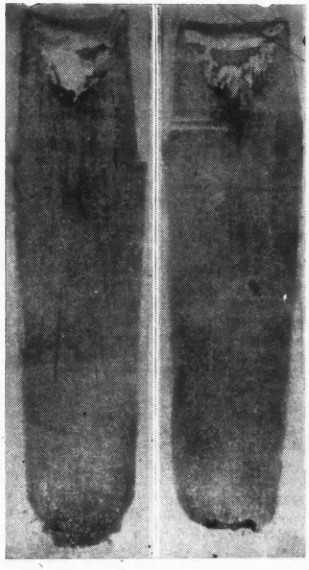


Fig. 1. Ingot mould for non-effervescing steel.

The weight of unsound metal which must be removed is smaller for the narrow type of sink head because the shrinkage hole is more sharply localised. The narrow type was, therefore, definitely adopted for production and this change, incidentally, was found to result in an appreciable reduction in the number of ingots suffering from transversal cracks.



a b

Fig. 2. Baumann Sulphur prints of longitudinal sections of ingot. (a) With narrow sink-head; (b) With wide sink-head.

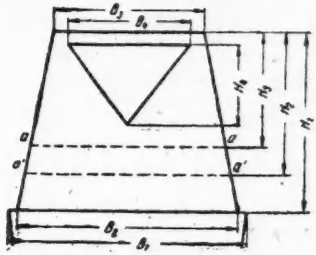


Fig. 3

Diagrammatic representation of sink-head metal: a a marks beginning of sound metal; a' a' marks beginning of sound metal with margin.

The next set of experiments was designed to investigate the effect on the grain structure of reduced filling levels and of covering the " hot top " surface with " Lunkerit," a powder composed of 18% metallic aluminium, 15% of 45% ferro-silicon, 12% bauxite, 25% charcoal and 30% burnt fire-clay. This was sprinkled on the surface of the metal immediately after pouring at the rate of 1 kg per ton of metal or 4.5 kgs total per ingot.

The quality of the ingot metal from the point of view of the central sponginess and local segregation was subsequently checked by the Baumann sulphur printing and deep etching methods on cross-sections of the rolled blooms.

It was found that with the use of Lunkerit, and by filling the narrow type of sink head mould to a level of only 400 mms. it would be practicable to reduce the weight of waste metal to only 15% of the total ingot weight, and to keep the defective metal entirely in the header. Any reduction in pouring level below 400 mms., however, resulted in an increase of waste to about 17%. The wide type of hot-top required a filling level of 360 mms. and the amount of metal to be removed generally worked out to 16%, but occasionally went down to 13%.

With the same filling levels and no Lunkerit there was 3 to 4% greater wastage of metal.

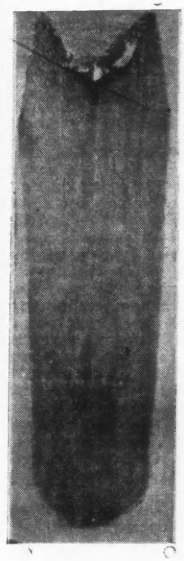


Fig. 4. Baumann sulphur print of longitudinal section of Lunkerit-covered ingot.

Conclusions.

1. It appears that existing practice as regards filling levels in sink heads is wasteful and pouring levels could be reduced from 500-600 mms. down to 500-450 mms.

without detriment to the quality of the metal.

2. Narrow sink heads are more economical as resulting in more localised shrinkage holes.

3. The use of Lunkerit reduces the weight of metal cut away in headers by 3 to 4% of total ingot weight.

4. The use of Lunkerit permits of reducing the filling level in sink heads to 400 mms., but further reduction in level is uneconomical.

TABLE I.

Dimensions and position of shrinkage hole in 4.5 ton ingots without the use of Lunkerit.

Melt	Type of	Dimensions in mms.								Weight in Kgs.			% of ingot weight			
No.	sinkhead	B_1	B_2	B_3	B_4	H_1	H_2	H_3	H_4	g_1	g_2	g_3	q_1	q_2	q_3	q_4
89	wide	650	550	470	450	550	460	430	280	1000	725	795	23.2	16.9	18.5	10.5
89	narrow	600	500	420	350	540	430	400	280	740	545	600	17.2	12.7	14.0	10.7
182	wide	650	560	470	450	430	410	380	290	765	640	760	17.8	14.9	17.6	13.4
184	wide	650	570	470	430	430	430	410	260	805	780	780	18.7	18.1	18.1	11.0
303	wide	650	550	450	360	480	410	380	300	810	645	745	18.8	15.0	17.3	8.7
433	wide	650	550	430	390	530	420	390	280	910	600	660	21.0	13.9	15.3	8.9
175	wide	650	570	440	400	500	470	470	300	900	820	820	20.9	19.0	19.0	10.0
232	wide	650	560	470	440	430	410	380	270	780	655	775	18.1	15.2	18.0	12.0
431	narrow	650	510	360	340	560	470	440	350	720	500	560	16.7	11.6	13.0	12.7
387	wide	600	510	420	380	500	510	380	250	745	515	575	17.3	11.9	13.3	11.2

g_1 = wt. of metal in sink head
g_2 = wt. of metal to line (aa)
g_3 = wt. of metal to line (a'a')

q_1 = % of total ingot weight in sink head
q_2 = wt. of defective metal in % of total ingot weight
q_3 = ditto, margined
q_4 = Volume of shrinkage hole in % of total volume of ingot.

HIRTH COUPLING, AN IMPORTANT MACHINE ELEMENT

By GEORGE MATZKE. (From *Werkstatt und Betrieb*, Vol. 74, No. 10, October, 1941, pp. 257-261).

A FUNDAMENTAL element or machine and engine construction is a rigid and positively locked joint, or coupling. The requirements of a well designed coupling are: efficient transmission of power, accurate and automatic centering, working safety and economy, and finally, it must permit easy assembling, dismantling and replacing.

The many types of joints used in various applications meet the above requirements to a lesser or larger degree only. A survey of all the joints would leave very little doubt in the engineer's mind that they comply with the demand for safety, accuracy, and replaceability in a very few instances only. Great attention has been focussed recently on Hirth couplings, and its rapidly increasing application can, no doubt, be attributed to the advantages it seems to offer.

The principal of design of a Hirth coupling is shown in Fig. 1. On the faces of the two hollow elements of the coupling (shafts), a and b, radial teeth are cut. The threaded tie bolt, c, holds the two parts tightly together and d is a small locking screw to prevent slackening of the tie bolt. The two serrated surfaces fit smoothly together, this being a fundamental condition for a positive closing between the parts. The teeth are radial to the axis of the coupling and the pressure between the two halves of the coupling ensures an automatic centering action.

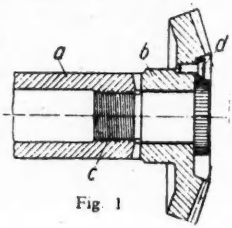


Fig. 1

The bearing pressure induced by the torque is carried by the teeth flanks. The flanks must bear, therefore, accurately on one another, and the whole of the flank surfaces must be in contact. For the cutting of Hirth coupling special precision milling machines are used for greater accuracy, finish grinding is only necessary with case hardened elements.

The teeth may be cut parallel or taper (Fig. 2) or double taper (Fig. 3). Whether they are cut parallel or taper the number of teeth is determined by the available space, purpose, torque and material. In general:

Up to 30 mm. outer diam., total number of teeth is .. 12
Up to 30-60 mm. „ „ „ „ .. 24
Up to 60-120 mm. „ „ „ „ .. 48
Over 120 mm. „ „ „ „ .. 96

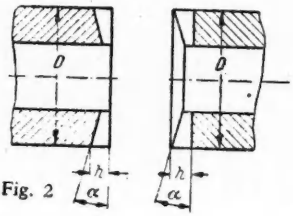


Fig. 2

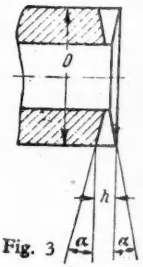


Fig. 3

Table I. gives dimensions of the teeth, while Fig. 4 shows the method of dimensioning from the transmitted torque.

TABLE I.

No. of teeth	H	r mm.	S mm.	h	Angle α with Parallel & taper teeth	Angle α with Double taper teeth
12	0.2260.D	0.3,0.6, 0.9	0.4,0.6, 0.9	H-(2r+S)	tan α = $\frac{2H}{D}$	tan α = $\frac{H}{D}$
24	0.1130.D					
48	0.0566.D					
96	0.0283.D					

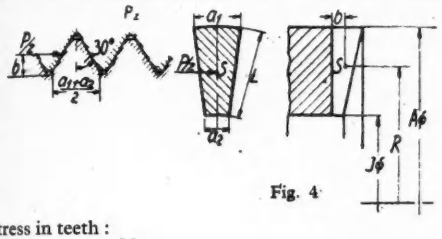


Fig. 4

Stress in teeth :

Torque $P = \frac{M_d}{R}$

Torque for 1 tooth $P_z = \frac{P}{Z}$

Bending moment for 1 tooth $M_b = P_z \cdot b$

Moment of resistance $W = \frac{L \cdot \left(\frac{a_1 + a_2}{2}\right)^2}{6}$

Bending stress $\sigma_b = \frac{M_b}{W} = \frac{M_b \cdot 6}{L \cdot \left(\frac{a_1 + a_2}{2}\right)^2}$

Stress in tie belt :

P=torque

P_a=arial force of Hirth coupling

F=area of cross section

$P_a = P \text{ ton} \cdot 30^\circ = 0.58 \cdot P$

hence

$$\sigma_z = \frac{2 \times P_a}{F} = \frac{1.16 \times P}{F}$$

where S=C.G.
R=Distance of C.G. from Centre
b=Distance of C.G. from tooth root
Z=Number of teeth
L=Length of tooth

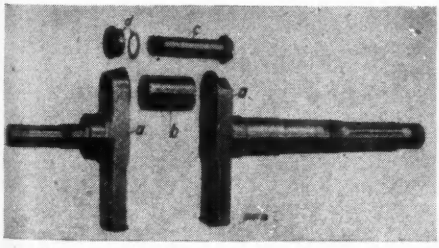


Fig. 5. Hirth coupling for a Star engine.

The shape of the coupling determines the type of tooth to be used ; as an example, on a flat profile parallel teeth are cut.

The maximum permissible stressing of the teeth, based on empirical data, is given in Table II.

TABLE II.

	Carbon Steel kg/cm^2	Cr-Ni and Cr-Mb Steel kg/cm^2
Static Stressing ..	900	1200
Dynamic Stressing	500	700
Dynamic Stressing by shock and torsional Oscillation ..	350	500

Hirth couplings promise great advantages ; it enables the engineers to solve constructional problems with great facility, which could not otherwise be solved satisfactorily. The field of application of Hirth coupling is very wide indeed, some of which are shown in Figs. 4, 5 and 6.

Fig. 5

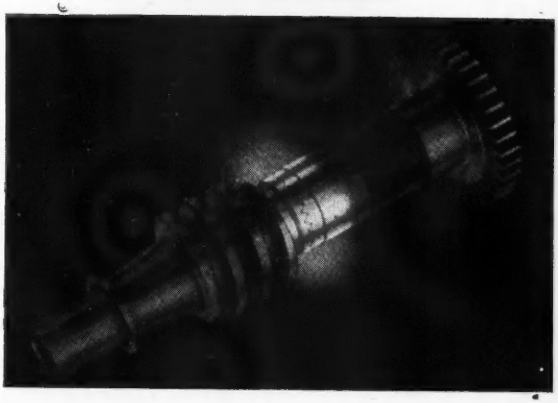


Fig. 6

IMPROVED BÜSSING N.A.G. PISTON HEAD FOR ANTE-CHAMBER DIESEL ENGINES

By ING. E. THEUMER. (From *ATZ, Automobiltechnische Zeitschrift*, Vol. 44, No. 20, October, 1941, pp. 505-507).

THE evolutionary progress of engine performance is guided by the aim of increasing power output and fuel economy without serious modification of engine design and dimensions. The index of such progress in Diesel engines is the ante-chamber type, because of its numerous and well-known advantages: reduced sensitivity to quality of fuel and timing of injection, small injection pressure reduces wear of nozzle and injecting mechanism, satisfactory pressure rise in main combustion chamber, relatively small peak pressure during combustion promotes smooth running, and finally, adequate turbulence in the ante-chamber manifests itself in efficient mixing of fuel and air.

A considerable improvement of engine performance is claimed by the Büssing N.A.G. manufacturers (Nurnberg) by the adoption of their new piston design (Fig. 1). The piston head has three channels (five in larger units) the cross-section corresponding to the dimensions of the spray of fuel/air mixture which enters the main combustion chamber from the ante-chamber. That is, the channels increase in section as the distance of the particular cross-section from the ante-chamber increases; consequently, the spray having a similar form, uniformly diffuses into the air during its passage.

The reason for this design is as follows; during the compression stroke air is forced into the ante-chamber at high velocity. Towards

Fig. 1

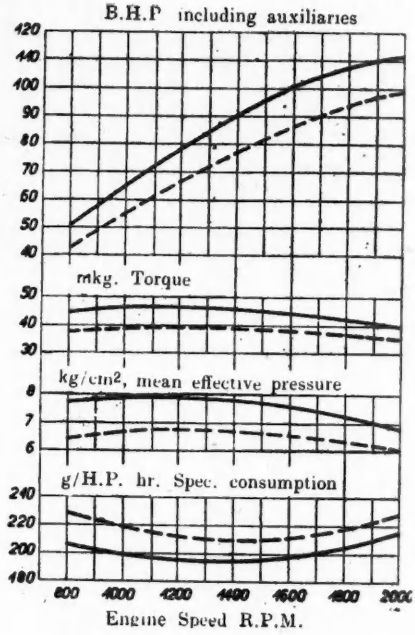


Fig. 2

——— Motor with dented piston.
— — — — Motor with flat headed piston.

the end of this stroke, fuel injection takes place and owing to the high pressure of the compressed air the fuel particles are finely pulverized. Ignition is started and the sudden rise of pressure drives the burning charge at great velocity into the main combustion chamber, where under the action of the kinetic energy of the rapidly moving particles actual combustion follows. Therefore, to ensure efficient mixing of air and fuel, it is most essential that the pressure in the ante-chamber shall considerably exceed that at the entrance to the main combustion chamber. If there is an accumulation of fresh air at the entrance, rapid combustion takes place and the pressure waves so set up repress or hinder some further charge from reaching the main combustion chamber. As a result combustion is appreciably slowed down, though there is sufficient amount of oxygen available for combustion. With the new piston design, the bulk of air accumulation is displaced far from the ante-chamber. In the immediate

vicinity of the entrance no appreciable pressure wave is set up and this way more fuel can enter the main chamber. The general effect of this is to speed up combustion.

Fig. 2 shows some results of tests made with the new and an old (flat headed) piston. The power output of the same engine was increased by about 15%, whilst the specific fuel consumption was reduced by about 6% with the new design. During a large crank angle rotation a high turning moment prevailed and the mean pressure was about 7.9 kg/cm² (112 lbs/sq. in approx.).

Some constructional detail of Bussing N.A.G. diesel engine, Type LD, is shown in Fig. 3 and 4. The engine fitted with the new type of piston, is a four-stroke, six-cylinder ante-chamber engine. At 2000 r.p.m.

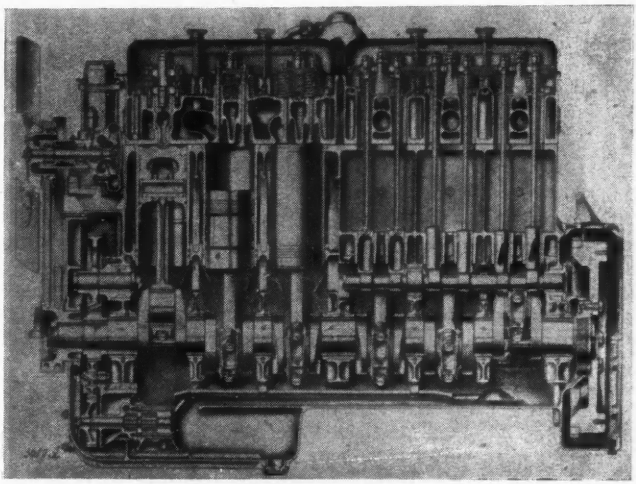


Fig. 4

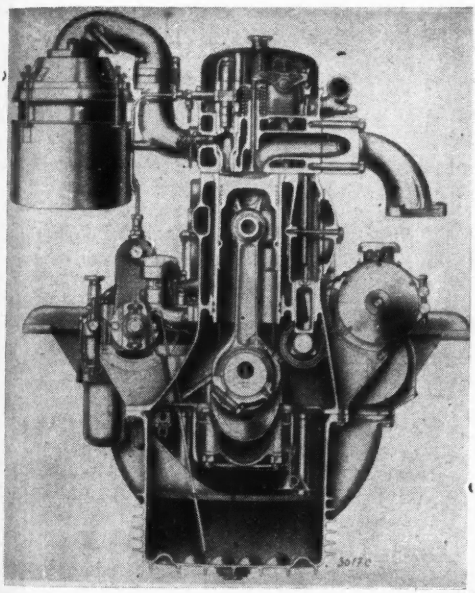


Fig. 3

it develops 112 h.p., but for prolonged working life the engine is run at a speed of 1800 r.p.m. The cylinder has a bore of 11 mm., stroke 130 mm. and a stroke volume is 7.4 litre. The crank case is brought up high and carries two cylinder heads and a flanged-on oil dash pot. The crank case is so constructed, that bending forces will not cause deformation. The water cooled cylinder liners are easy to remove and are centrifugally cast. The crank shaft itself is supported by 7 steel armoured gun metal bearings.

The connecting rod big end is made of two parts bolted together along a line some 35° to the vertical, so that the connecting rod can be dismantled through the cylinder.

The cam shaft if mounted on four replaceable bearings, and is driven through a helical gear pair. A gear pump is used for lubrication of bearings, etc. The cylinder liners and gudgeon pins are lubricated by a fine spray.

Tests have also shown that ante-chamber type diesels with the new shaped pistons are not sensitive towards vaporising properties of the fuel; heavy oils with high ignition temperatures, too, can be used with favourable results.

THE STRENGTH OF BLAST-FURNACE COKE

By Prof. Sapozhnikov. (From *Stal*, Moscow, 1941, No. 4, pp. 3-11).

Analysis of Breaking Up Process.

The breaking up of coke on the way to and inside the blast furnace is unlike a usual mechanical grinding process in not being "selective"; in other words there is no tendency for the larger pieces to be crushed before the smaller ones.

The U.S.S.R. Institute of Mineral Fuels has devised an apparatus of the rotating drum type,

which imitates quite closely this natural crumbling process. A test of coke strength can be effected by counting the number of revolutions of the drum required to obtain a certain degree of fineness, but a more satisfactory method is to work to a standard number of revolutions (200 actually) and to analyse the condition of the coke before and after the test.

The only satisfactory form of quantitative analysis is by means of a series of successive screenings, the result of which can be plotted as shown in Fig. 1. It is found convenient for this purpose to disregard completely very small pieces which pass through a 15 mm. gauge screen, because undue extension of the curve towards the right unnecessarily multiplies the chances of inaccuracy. Should it be desired afterwards to assess the number of the smaller pieces present, this can be done as explained further on.

In Fig. 1, Curve 1, represents the original state of the coke, Curve 2 that after 200 revolutions of the drum. Curve 3, corresponding to 600 revolutions is only given by way of completing the picture, and is not normally required.

It will be seen that the area below such a curve represents the total number of pieces of coal per 100 kgs, and also that by superimposing Curves 1 and 2 we get on the right hand side the shaded area Σ_o, which represents the number of small pieces newly created in the course of the disappearance of a certain number of large pieces corresponding to the shaded area Σ_p. The ratio

$$f = \frac{\Sigma_o - \Sigma_p}{\Sigma_p} = \frac{\Sigma_{final} - \Sigma_{initial}}{\Sigma_p}$$

can be termed the " characteristic of the breaking-up process." This is a constant for all stages of a process, but varies a good deal as between different varieties of coke.

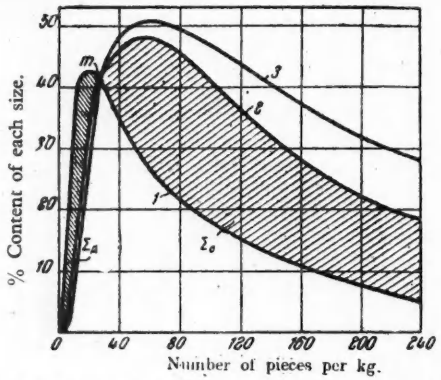


Fig. 1. Curves of screening analysis results for three stages of break-up of a typical blast furnace coke.

To describe a process completely it is also necessary to know the initial condition of the coke ($\Sigma_{initial}$) and the extent of advance of the process of breaking-up. In our system, the latter quantity is termed " degree of break-up " and measured by evaluating the area Σ_p. (This is justified, because $f\,\Sigma_p = \Sigma_o - \Sigma_p$ = increase in the number of pieces per 100 kgs and f is a constant for any particular type of coke).

The entire process in all its stages, therefore, can be represented by a straight-line graph, such as the three typical ones shown in Fig. 2.

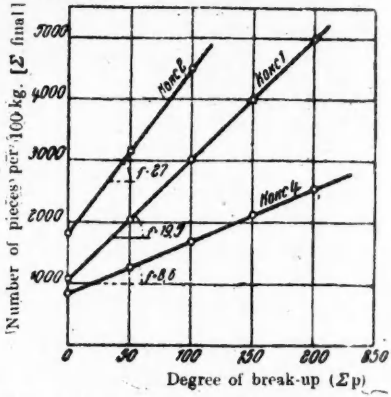


Fig. 2. Break-up processes of three types of coke.
(Kokc 1). Cokc made of a blend of 70% gas coal and 30% dry coal.
(Kokc 2). Cokc made of 80% gas coal and 20% dry coal.
(Kokc 4). Cokc made of 55 rich and 45% dry coal.

Once the values of f and Σ_p are known it is possible to calculate, if desired, the number of pieces of smaller mesh than those taken into account during the experiment. Coefficients " K " have been worked out for the various finer meshes, and experiments have shown that the amount of coke in any class is always :

$$a\,\% = K.f.\,\Sigma_p.$$

The value of K is 0.001 for the 5-10 mm. mesh, 0.002 for 10-15 mms. and so forth, varying somewhat for varying types of coke.

Physical Condition of Coke in Blast-Furnace.

Having evolved a simple and comprehensive system of analysis, the next step was to obtain and analyse samples of coke from various levels inside a blast-furnace in operation. Samples were obtained from various furnaces in Magnitogorsk and Zaporozhie (Donetz Basin). The great majority were taken out, in batches of 300-500 kgs at a time, through the tuyeres during short interruptions, but a few came from other levels. In some cases the samples were all taken

along the radius up to the centre of the furnace, in others it was only possible to go inward 1 to 1.5 meters.

After withdrawing, the burning coke was extinguished by dispersal. When cold, it was hand-sorted to exclude all pieces of slag, iron, etc., then screened for classification as before. From samples obtained simultaneously at different levels it was quite clear that the actual breaking-up process in the furnace corresponded very closely to that obtained during laboratory tests on identical cokes, actually taken from the furnace bunkers.

The most interesting result of these experiments was this: For cokes of widely varying qualities the "degree of break-up," p, at tuyere level was practically identical, varying only between the values of 220 and 265 with an average value of 240. Yet to reproduce experimentally this degree of break-up, some of the coke required as little as 100 revolutions of the drum and others as much as 550. In fact, the softest coke of the lot showed very nearly the lowest degree of break-up in the furnace.

In other words, the result of experiments determining the "hardness" of coke is no guide whatever to its behaviour in the furnace. The authors of various mechanical devices for testing the hardness of coke have assumed that a standard amount of work done on a sample coke, represented by a standard number of revolutions of a drum or some such device would reproduce the behaviour of the material in the furnace. But we now hold clear practical proof that to reproduce furnace conditions one must expend 5 1/2 times more work on a hard coke than on a soft one, so that the whole meaning of the conventional "hardness" experiments is destroyed.

Yet there still remains the fact that coke may break-up too freely in the course of its journey down the furnace stack with consequent danger of choking. Having discarded the "hardness" principle as misleading we must apply the method of analysis previously explained.

Thus Σ tuyeres $= \Sigma$ hopper $+$ 240 f. for furnaces in normal operation.

Table I. shows how closely the practical results (column 5) correspond to the figures as calculated by the above formula, given in Fig. 6. Incidentally it illustrates clearly that although the degree of break-up, 2p, is constant, this does not mean, in the least, that the coke at tuyere level always gives identical screening analysis.

TABLE I.

Comparison of calculated and actual fineness of coke at tuyeres for cokes from different localities used in different furnaces.

Coke No.	Break-up characteristic "f"	No. of pieces of over 15 mm. gauge per 100 kg. At hopper (Σ_{hopper})	At tuyeres	As calculated: ($\Sigma_{tuyeres} = \Sigma_{hopper} + 240$)
1	17.8	5,400	10,335	9,680
2	13.8	3,450	7,300	6,770
3	13.7	3,210	6,875	6,510
4	14.0	2,260	5,560	5,620
5	12.3	2,476	5,335	5,426
6	12.0	1,800	4,480	4,680

Conducting the investigation further, it was found that:—

(a) The blend of coal used in making the coke will, of course, affect the break-up characteristic "f" very strongly. This will be clear from Fig. 2, and the coke composition figures given below it. It may here be added that although, of the three cokes given in Fig. 2, the lowest "f" corresponds to the highest dry coal content, further advance in that direction reverses the trend. The "f" of a blend containing 60% dry coal and 40% rich was found to be 12.5.

(b) Another most important factor affecting resistance to crumbling is the length of coking time. The longer the period in the coke oven, the larger the pieces at blast-furnace tuyeres. "Hard" cokes made in 13.5 hours have broken up finer by the time they got to tuyere level than very "soft" products of 17 to 19 hour processes.

(c) Σ_p rises rapidly if the coke is kept in the furnace longer than usual. This is particularly noticeable in the lower levels and accounts for the choking experienced when the tempo of operation is slowed down. The degree of break-up is also considerably greater near the centre of the furnace than near the sides, due to higher temperature. It will be clear, therefore, that if a furnace is working with a high slag content, and particularly if the slag is viscous, it is essential to choose a coke which will result in low calculated "Σ tuyere": fine coke will slow down the process resulting in still greater crumbling until choking will result. On the other hand, free-flowing slags permit of using a coke with high "Σ tuyere" value.

THE METALLURGY OF MANGANESE

By GEORGE VOLKERT. (From *Stahl und Eisen*, Vol. 61, No. 41, October, 1941, pp. 938-940).

THE metallurgy of Manganese has two distinct problems:

(1) The production of high-carbon Manganese alloys, up to about 85% Mn and 7% C, and

(2) The production of low carbon Manganese

alloys, down to the lowest possible carbon content.

Case 1 bears some similarity to the metallurgy of iron, but when it comes to de-carbonisation, the re-action $4\ Fe_3C - Fe_3O_4 = 15\ Fe - 4\ CO$ becomes impracticable for Manganese alloys. A metal bath containing Silicon, Manganese, Iron, and Carbon, when treated with a slag rich in Manganese or Iron, will bring about oxidation of the Silicon and Manganese content first, and only then is the Carbon content oxidised. In other words, the Silicon content is reduced, Manganese oxide is formed, but the carbon content remains unaltered.

Many patents are based on this behaviour of Manganese alloy, for the production of high Silicon content Manganese alloys. The production of such alloys has thus lead to the important fact that with identical iron content, the Silicon/Carbon ratio is fixed. Fig. 1 shows the variation of Carbon content with Silicon content for a particular Iron content. As an example, with 22% Si and 70% Mn, the Carbon content cannot exceed 1%. Excess Carbon separates out from the fused alloy during a slow rate of cooling as graphite flakes, while with rapid cooling the carbon will not be evenly distributed in the alloy; in this case the composition at the outside will be 66% Mn, 24-26% Si and 0.6-0.8% C, and at the inside, 72-74% Mn, 16-18% Si, and 1.5-2% C. The high Si content at the outer part of the alloy will show itself by the coarse granular structure and the shiny-white surface of the fracture, while the core shows a grey fracture and a fine structure. The Silicon Carbon ratio varies with the Iron content.

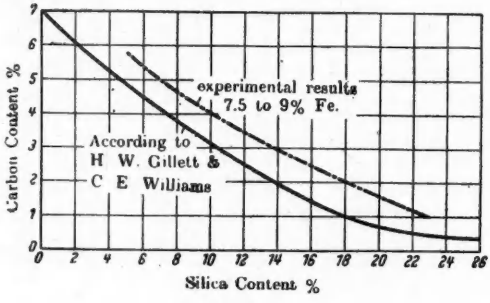


Fig. 1

The problem of obtaining a low carbon Manganese alloy is now simplified to that of processing a Si-Mn alloy with a ratio of Mn:Si = 1:1. This alloy will necessarily be of low carbon content and when it is oxidised, the Silicon content is first eliminated, the low carbon content remaining unchanged. The production of Si-Mn alloy is possible by the following three main methods:

(1) From Manganese ore + Quartz + Carbon.

(2) From Manganese rich slag or silica free Manganese ore.

(3) From blast furnace Ferro-Manganese + Quartz + Carbon. The Si-Mn alloy is almost invariably produced in electric furnaces, preference being given to A.C. furnaces. Actually the same installation can be used as that used for the manufacture of Ferro-Silicon.

To method 1. The mixture (charge) is continuously admitted to the furnace and the recovered alloy is periodically tapped off. The molten metal should be prevented from rising to the surface of the furnace charge, to prevent heat losses which is utilised during correct operation for the pre-heating of the fresh charge. It is imperative to keep the evaporation losses as low as possible; under favorable conditions these losses amount to 10% only, while unfavorable operational conditions raise this to 20%. Evaporation losses are mainly due to:

(a) Too deep immersion of the electrodes in the metal bath, causing local overheating of metal beads which then vaporise and escape upwards.

(b) Accumulation of too much metal in the furnace; the operation becomes irregular, due to short circuit impulses with consequent evaporation, and

(c) By using too strong a reducing agent: in this way the reduction zone extends up to the surface of the bath, the path of the metal beads being thus prolonged, and this may provide ample opportunity for evaporation.

It is very important with this type of operation to adjust the zone where the oxidation takes place very carefully with respect to the tap holes. The depth of immersion of the electrodes is namely regulated by the adjusted maximum voltage; if the charge in the furnace is increased the electrodes will take more current (the charge is slightly conductive), the voltage will drop and the regulator will, therefore, raise the electrodes. The "reaction" zone is now higher, and eventually a state might be reached when the tap hole lies below the mass of the liquid alloy. In such instances the furnace must be kept working for a longer period, or alternatively, the voltage across the electrodes must be temporarily reduced.

To method 2. Considerably more difficult is the recovery of Si-Mn alloy from silica free ore and slag. At the beginning of this war experiments were carried out to this end, and the best conditions determined for Manganese recovery from slag having the following composition:

TABLE I.

Slag	I %	II %	III %
SiO_2	32.20	33.60	30.70
Al_2O_3	2.90	—.—	2.30
FeO	0.40	—.—	0.63
CaO	18.75	33.12	28.20
MgO	18.10	—.—	7.50
MnO	27.20	21.94	29.30
BaO	—.—	—.—	2.53

A 1000 KVA A.C. furnace was used, and the aim was to obtain Si-Mn alloy and Manganese free slag. The charge consisted of 3000 kg slag, 180 kg coke, 400 kg Calcium, and 200 kg ore.

Again it was found that increased basicity of the slag improves the Mn recovery (Fig. 2).

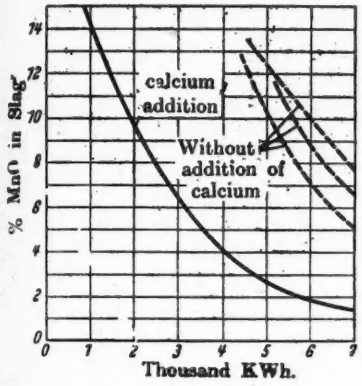


Fig. 2

From Table II the beneficial effect of calcium can be seen with respect to the power consumption. The power consumed for the recovery of a certain amount of Manganese was reduced from 14,420 to 12,430 KWh when the calcium content was increased. In case II and IV, additional ore was used, and case IV illustrates the effect of adding FeSi to the mixture. Actually, this was done with the view of increasing the Silicon content in the recovered alloy, but this was not achieved. The composition of the recovered alloy was for case I, II, and III, 80-85% Mn, 4-7% Si, 4-6% C, the rest being iron. For case IV the final composition was 77-80% Mn, 10-12% Si, and 2-4% C.

TABLE II.

	Slag kg.	Ore kg.	Calcium kg.	Coke kg.	Fe-Si kg.	Electrodes	KWh	Duration
I	6650	—	470	780	—	—.—	14,420	9 days
II	6650	—	885	810	—	—.—	12,430	8 days
III	5540	387	1000	674	—	157	12,050	8 days
IV	5020	346	808	595	155	92.5	10,055	20 days

It can be said that the total loss through evaporation amounted to about 15-20% Mn. The actual quantity of Mn in the alloy was 70%, and this could be raised to a higher value only at the expense of more power, by prolonging the melting period. With smaller Manganese concentration in the bath, silica is reduced in a larger proportion from $CaO.SiO_2$, whereby the energy consumed was considerably greater than that required for the oxidation of Quartz and Si from a Ferro-silicon charge. Owing to the economical disadvantages further experiments were abandoned. The alloy recovered by this process was unsuitable as for either a high carbon Manganese alloy or as Silicon-Manganese. The only possibility was, therefore, to increase the Silicon content further, and hence to process 3.

High carbon Manganese alloy + Quartz + Carbon.

This method, too, was carried out and tested in a 1000 KVA A.C. furnace. The charge was admitted continuously, while the alloy was tapped off at intervals of 3 or 4 hours. The charge consisted of 800 kg Quartz, 200 kg Coke, 1200 kg high-carbon Manganese alloy (from melting of the slag). It was aimed to increase the Si content sufficiently to keep the Carbon content below 2% in the resulting alloy. The furnace was "dry" operated, i.e., without a fluid bath at the top of the charge. An average daily production of 6000 kg was obtained. For each ton of Si-Mn alloy produced, 1032 kg of high carbon alloy, 775 kg Quartz, 305 kg coke, and 3945 KWh was used up. The resulting alloy had the following composition 63-67% Mn, 30-31% Si, 5.5% Fe, and 0.1-1% C.

With this method some 97% of the Mn and 64-66% of the Si content was recovered. The latter figure is, of course, much too low, but it should be remembered that practice has shown that the utilisation of Si charge decreases with smaller furnaces.

These results incited engineers to try and convert the high-carbon ferro-manganese alloy by this method to a 1% C Ferro-Manganese alloy. One difficulty resulted from the high iron content, and it was only found possible to convert 10-12% Fe alloys. To convert this to the required alloy, either high-carbon Ferro-Manganese + Quartz + coke, or Manganese ore, + Quartz + coke was used. The charge consisted, therefore, of 125 kg high-carbon Ferro-Manganese (85% Mn), 360 kg Mn ore, 210 kg Quartz, and 200 kg coke.

With this charge a uniform furnace operation could be obtained. Owing to the higher metal

content of this charge, the voltage across the electrodes had to be reduced slightly, to bring the electrodes deeper into the charge, or bath. The recovered alloy was of the following composition: 64-66% Mn, 22% Si, 7-9% Fe, and 0.5-1% C. This alloy can then be subjected to the usual treatment to reduce the Silicon content, in an arc furnace.

GAS FUEL FOR FOUNDRIES

By W. CALLENBERG. (From *Die Giesserei*, Vol. 28, No. 14, July, 1941, pp. 311-313).

THE consumption of large quantities of gas by the steel industry in Germany is not only a consequence of economical considerations, but also of the demand for high quality products, protection of the labourer, and certain technical possibilities, all of which necessitate the use of a first class fuel—such as gas.

Foundries and allied industries become more and more aware of the fact that gas fuel, compared with solid fuels, promises favourable technical features especially with respect to light load operation and sanitary aspects. Today there are a large number of foundries in Germany, mainly light metal foundries, which can be classified amongst the large gas consumers.

Progress to this end was particularly influenced by the fact that many foundry plants had to be extended to include new operations as well, demanding gas-furnaces, drying chambers, etc. War time conditions, too, played an important part in the change over to gaseous fuels.

As an example, liquid fuels were confined to applications where their use deemed imperative and the quantities involved were small. In all other instances the plants had to be re-designed for gaseous and solid fuels. The consideration of the quality of the products prohibited, at the same time, the use of inferior "cheap" fuels.

However, before the use of high quality fuels, such as gas, was generally accepted some prejudices had to be overcome. A prejudice was, as an example, that gas fuel in melting processes will increase the water content of the material—a theory lacking almost all foundation and true only, in some special instances. Many a melting plant, formerly oil burning, were converted to gas heated plants and by appropriate regulation of the furnace atmosphere, the water content could be adjusted to any desired value. Practical executions have shown that the thermal efficiency and general operation of foundries were appreciably improved with gaseous fuels.

The growing demand for mass production joined with high quality of the work promotes the importance of faultless and quick drying apparatuses for the foundry.

Inefficient, slow drying is responsible for time losses which cannot be tolerated. But gradually improving the drying technique and by using gas heated drying plants this problem can be regarded as completely solved. The chief requirement made of drying plants is easy regulation and uniform temperature inside the furnace within 5% temperature variation; both these conditions are easy to meet by using gas drying units. Electricity for such purposes would not satisfy the economical requirements, although otherwise would afford satisfactory means for heating.

The engineer is given a great choice of gaseous fuels for foundry plants. Town gas and gas supplied from a long distance compare favorably with blast furnace gas, coke oven gas, and producer gas, owing to their almost identical calorific values. The main objection against blast furnace gas is that this does not ignite readily, and this way may be responsible for accidents. Similar drawbacks are inherent to producer gas, yet with the difference, that whereas the latter is specially prepared and requires therefore additional apparatus and room, blast furnace gas is a by-product by necessity. Apart from this, generator gas is economical only if there is a uniform consumption, usually not the case in foundries, and can, therefore, not compete with coke oven gas.

Town gas is probably the most suitable for such purposes; constant readiness, permission of non-uniform consumption, cleanliness, good regulation, etc., are some of the advantages it can offer. A further advantage is better dimensional stability of the mouldings which indirectly leads to economy in raw materials. But as mentioned before, there still exists a disagreement between engineers, regarding the suitability of gas for foundries and this prevents, for the time being, a universal adoption of gaseous fuel.

Up-to-date drying units are manufactured in all sizes, and the many types on the market are able to satisfy various conditions and specifications. Another very advantageous field of application for town gas is pre-heating of moulds. No other pre-heating system operates so satisfactorily. There is also a considerable saving in time, as for instance, compared with coke operated pre-heaters, the saving is about 60%.

Apart from these and many more applications not mentioned here, gas heating is almost a perfect means of consolidating working conditions, and in this fashion forms a mile stone towards the uniformity of production. Regarding economy, it is suggested that a close control of the gas consumption and statistics might be of great help to approach ideal conditions, which can be predicted by calculation.

SYNTHETIC FOILS SAVE METAL

By HANS BECK. (From *Kunststoffe*, Vol. 31, No. 7, July, 1941, pp. 260-265).

SYNTHETIC foils (films), manufactured from cellulose and fully synthetic materials, found application in the optical and electrical industries for many years. The requirements of foils, with special regard to their optical and dielectrical properties, inhibit competition between synthetic and metallic foils in many applications, and these types of foil are, therefore, omitted from this article. On the other hand a number of transparent, mechanically strong, synthetic foils, other than viscose, have been developed during recent years, and because they possess remarkable adaptability for packing purposes, they can be substituted for metallic foils. The saving in metal made possible this way is greatly assisted by the development of mechanical methods of processing them.

General Remarks on Polyvinyl Chloride Foils.

In the first place Polyvinyl chloride foils deserve mentioning as they exhibit properties superior to many types of packing foils, as for instance paper, cardboard, cellulose, impregnated or lacquered materials. Their principle characteristics are as follows:

(1) Chemically very stable.
(2) Mechanically strong.
(3) Light, and resistant to ageing.
(4) Permeable to steam.
(5) Odourless, tasteless, transparent, almost colourless.
(6) General applicability.

The commercially available Polyvinyl chloride foils differ mainly in the processing which, however, is based in each case on a mechanical method. A subdivision of foils is based on their thickness; one group includes foils of a thickness of 0.3 to 1.0 mm., and the other of 0.02 to 0.06 mm. Those of the first group are successfully used in machine design as protective packing against corrosion, while the thin types (so called fine-foils) are employed for insulating and packing purposes by the electrical industry.

Rough Foils (Vinidur Packing Foils).

In the packing industry, Vinidur foils are being used as substitutes for metals. Drawn drum containers are made of Vinidur by a drawing process which is basically the same as that used for lead. As the manufacturing costs of such containers exceed that of metal, their use is only justified at present by consideration of supply and the economy of metals. Folded seam containers can also be made of Vinidur foils, the folding, of course, being replaced by gluing as the folds alone would not hold. In such applications only the shell of the container is of synthetics, while the two ends are made of metal. There are several processing methods known, each making use of the ductility of the Vinidur foils. Drawing can be performed at normal room temperature.

A typical drawing tool, one which was proved in production, is shown in Fig. 1. The Vinidur foil is fed to the machine by hand. The first operation is cutting, done by the downward stroke of the drawing plate between the outer cutting edge and cutting ring. During this operation the foil is held in position by the draw plate and the work holder, the latter being forced upwards by a spring. Next, the foil is drawn over the core and a cutting plate trims the edges straight. The finished container cover is now lifted by the top part of the machine and is automatically ejected from it by the ejector-plate. The drawing clearance must have suitable dimensions.

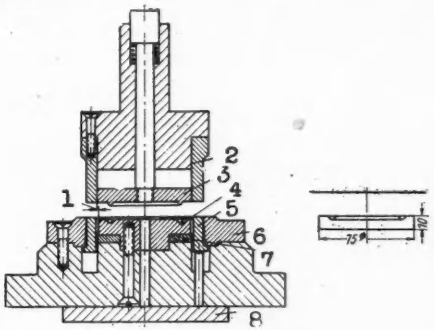


Fig. 1

(1) Drawing clearance; (2) Draw plate; (3) Ejector plate; (4) Core; (5) Work holder; (6) Cutting ring; (7) Cutting plate; (8) Disc pressing against spring.

As mentioned before, drawing takes place at room temperature. By using a crank or an eccentric press, the best speed is about 20 r.p.m. In an endeavour to increase the working speed, it was found possible to increase the speed of the upward stroke, while an arrest was arranged when the top half was in the lowest position; this was necessary owing to the elastic after-effect of the finished article.

The ductility of Vinidur foils is remarkable. Actual flowing of the material takes place during drawing, and consequently the specified foil thickness can be exceeded without affecting the result. Tolerance of thickness amounts to about 20%.

The bottom cover of the container is fabricated in the same fashion, and although the drawing depth is larger, the working speed is the same. The following are suitable dimensions for the drawing clearance:

Nominal Thickness	Actual Thickness	Width of Drawing Clearance
0.4 mm.	0.36 to 0.44 (0.48) mm.	0.28 mm.
0.6 mm.	0.54 to 0.66 (0.7) mm.	0.38 mm.

Drawn Vinidur foil containers are suitable for packing all sorts of articles, especially pharmaceutical products and cosmetics.

Fine Rolled Foils.

By these, mechanically processed foils of thickness of 0.02 to 0.1 mm. are understood. Such products manufactured by many firms in Germany are sold on the market under the name of Igelit, while a similar product processed by the I.G. Farbenindustrie A.G. is called Luvitherm. The raw material basis to these products is common, and they have similar stability, solubility, and physical properties to those of the Vinidur foils. Igelit has a reddish-brown colour, while Luvitherm foil, owing to more careful manufacturing process, is colourless and has a shiny, bright, surface.

Mechanical Strength.

Luvitherm is manufactured in two types: Type G is characterised by a much greater tenacity in the longitudinal direction than in the lateral direction; this is obtained by a special process, by which a special linear molecular arrangement takes place, accompanied by the strengthening of the foil in one direction. Type GU is the standard type. Some figures of mechanical strength for fine-foils are given in Table I. Tables II. and III. show the effect of certain treatments upon the properties of the foils.

Table III.

(Elongation of Fine-Foils).

Treatment	Luvitherm Type UG	Luvitherm Type G	Fine Rolled Foils
24 h. in dry air at 60°C	$< \pm 0.1\%$	-0.3%	$< \pm 0.1\%$
24 h. in dry air at 100°C	$< -1\%$	-40%	-5%
24 h. in water at 20°C	$< +0.1\%$	—	$+0.1\%$
24 h. in water at 60°C	$+0.5\%$	-0.5%	$+0.5$ to 1%

Table IV.

(Water absorption of fine ½ rolled foils. Increase in weight in % after period in water).

	After 48 h. at room temp.	After 2 h. at 100°C
Luvitherm:		
Type G and UG	0.5 to 2	10 to 20
Fine rolled foils	1-to 2	35 to 45

Table I.

	Thickness mm.	Strength kg/cm² Transvers.	Strength kg/cm² Longitud.	Elongation % Transvers.	Elongation % Longitud.	Impact strength cmkg/cm² Transvers.	Impact strength cmkg/cm² Longitud.	Folding Number (Schopper) Transvers.	Folding Number (Schopper) Longitud.	Dimensional Stability up to °C
Luvitherm Type G	0.03	400-500	1200	5	20	100	2000	1000	>10000	80
Luvitherm Type UG	0.04	500-700	500-700	20	30-50	250	250	>10000	>10000	130
Fine-foil	0.02-0.04	500-600	500-700	6-12	20-30	100	400	2000	5000	110

Table II.

	Thickness mm.	Strength kg/cm² Longitud.	Strength kg/cm² Transvers.	Elongation % Longitud.	Elongation % Transvers.
		After 48 hours in dry air at 80° C.			
Luvitherm G ..	0.020	1300	300	15	5
„ „ UG ..	0.035	600-700	600-700	20	15
Fine rolled foils ..	0.030	550-600	550-600	10	5
		After 48 hours in dry air at 130° C.			
Luvitherm G ..	0.020	750-850	650-850	30-40	5
„ „ UG ..	0.035	600-700	600-700	20	15
Fine rolled foils ..	0.020	800-900	700-800	20	5
		After 48 hours in water at 20° C.			
Luvitherm G ..	0.020	1000	300	15	5
„ „ UG ..	0.035	500	500	30-50	10-20
Fine rolled foils ..	0.030	450	300-500	20	5

Water Absorption Capacity.

In a water bath, Igelit foils absorb water. The quantity absorbed depends mainly upon the duration and temperature of the bath and are shown in Table IV. As a secondary phenomenon tarnishing of the transparent foils occurs, but the mechanical strength is not affected.

Permeability to Steam.

Distinctly apart from the previous phenomenon, and independently from it, fine-foils allow the passage of a certain amount of steam or vapour when in contact with the liquid or humid air. This can be regarded as a " diffusion," and the coefficient of diffusion was found to be

$$7 \times 10^{-9} \text{ g/cm h Torr.}$$

The coefficient is valid between about—15° and +90° C. The coefficient of diffusion is proportional to the pressure difference at the two sides of the foil, and is inversely proportional to the foil thickness.

Fig. 2 shows the diffusion curve in dependance of temperature. In Fig. 3 logarithmic values are plotted and the linear performance of the graph indicates that the coefficient is a constant.

It must be remembered, however, that static conditions do not prevail in practice, and consequently an apparent change of the coefficient of diffusion can be observed. In addition proper sealing of the ends (e.g., when foils are used for packing cables, etc.) is essential in order not to jeopardize the sealing properties of the foil. The closing of the ends is usually by gluing or by homogeneous welding. Tests have shown that the permeability of foils is unaffected by small (microscopic) pores in the material.

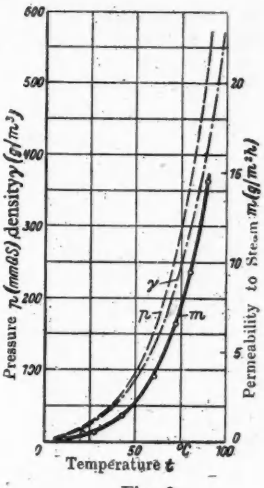


Fig. 2

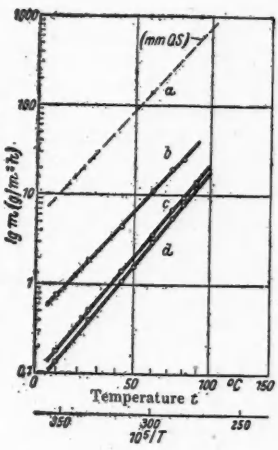


Fig. 3

Application.

The possibilities of metal saving are most interesting. Igelit represents a high quality packing material, and in many instances, where complete sealing from vapour is not essential, it can be used as a substitute of metallic foils. Combination of the two is also sound practice.

Synthetic foils are frequently used, not as a direct packing material, but rather as an improvement to packing, by an auxiliary covering to prevent the actual packing from drying out or becoming wet. For this purpose Igelit was found successful as it possesses very good cohesive properties which are not adversely affected by heat.

UTILIZATION OF STEAM PASSENGER LOCOMOTIVES

By A. A. RAYMOND. (From *Mechanical Engineering*, Vol. 63, No. 12, December, 1941, pp. 870-874).

IT is axiomatic that greater utilization of locomotives can be hoped for only if the locomotive gives reliability of performance. The measuring stick of the movement of trains is the on-time performance, the success or failure of which is shown in reports, reaching the mechanical department daily, of delays to trains owing to mechanical difficulties resulting in lost time that could not be made up.

Many improvements have been made in steam locomotives, such as: Decrease in weight per unit of power, one-piece locomotive bed, cylinders and frames cast integrally, roller bearings, refinements in maintenance, etc. These improvements have increased very materially both the reliability and the capacity of the machine. If time permitted the definite results of each of these items could be discussed, but for illustrations the improvements attributable to roller bearings will be considered in detail.

Effect of using roller bearings.

To demonstrate the improvements due to roller bearings, the record is given in Table I.,

for 9 years starting in 1927, when all engine trucks were equipped with friction bearings.

Table I.

(Before application of roller bearings on engine trucks).

Year	Miles per day
1927	373,295
1928	814,469

(All important passenger locomotives equipped with roller bearings).

1934	14,486,923	(No delays)
1935	15,480,723	
1936	15,754,913	
1937	17,624,429	(No delays)
1938	19,261,201	(No delays)
1939	19,379,594	
1940	19,780,391	(No delays)

About 1929, roller-bearing engine-truck applications were started in substantial numbers, and in 1934 practically all high-speed passenger locomotives had such engine trucks. At that time more than 14,000,000 miles per year were made with no delays chargeable to this cause.. During 1940 with better than 19,000,000 miles there were no delays. In the last five years the locomotives made approximately 90,000,000 miles with only two delays, which would indicate 45,000,000 miles per delay, whereas, in the first five years of the report, miles per delay averaged approximately 500,000, which means that the roller bearings decreased the liability of delays 90 times.

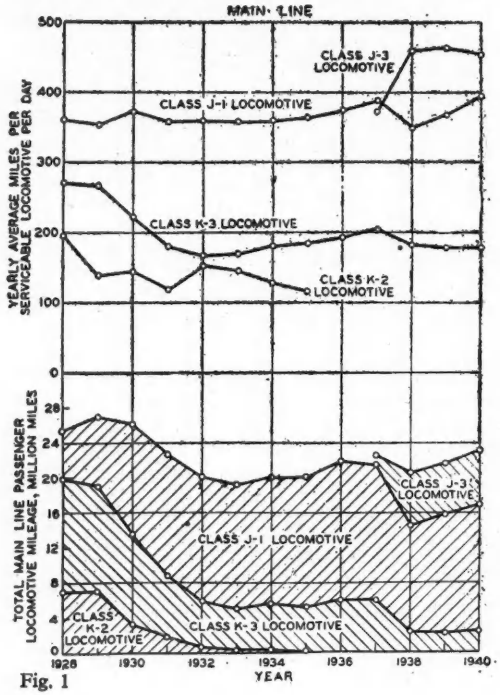


Fig. 1

In the eight-years period (1933-1940) it is found that on tender trucks the roller bearings made 60 times the mileage of the friction bearings per delay. Trailer trucks with friction bearings during the same period made 200,000 miles per delay, while with roller bearings there were 5,000,000 locomotive miles per delay.

Perhaps the confidence the railroad has in roller bearings can best be described by saying that there are 350 locomotives equipped with engine truck roller bearings, 309 locomotives with tender-truck roller bearings, and a total of 84 locomotives, including all the newer locomotives, with roller bearings on driving boxes.

Another improvement that has a direct bearing on utilization of power is water treatment. Frequently, it was necessary to wash the boiler on arrival, but with full water treatment the number of days between washouts has been extended so that the majority of engines can be promptly made ready for service.

With the one-piece cast-steel bed many separate parts and several hundred bolts have been eliminated, all of this contributing further to the reliability of the machine and reducing engine-house maintenance.

The proof of reliability.

It may be said that all of the foregoing is true, but perhaps it has not been possible to take advantage of these improvements. To explore that possibility, the upper portion of Fig. 1 shows the average miles per serviceable locomotive-day for the last twelve years. This chart covers all of the locomotives of each of the classes handling all main traffic, that is, important trains, trains of less importance, and local trains, and providing the necessary reserve locomotives to insure the prompt operation of any extra trains or to meet any condition requiring more locomotives.

It will be observed that the older K-2 locomotives were averaging about 200 miles per day in 1928, but the K-3's were appearing in substantial numbers with an average of 270 miles per day, a material improvement. This average daily mileage for the K-3's continued for about a year. Then the J-1's arriving in substantial numbers immediately began to make 360 miles per day, which has been maintained with an improvement in recent years.

At the bottom of Fig. 1 is shown the total main-line passenger-locomotive mileage made each year. This additional information is given to illustrate the fact that not only did the newer locomotives individually handle more miles, but the newer type of locomotive also handled increasing percentages of the total business available.

Sometimes it is asked if in former years the locomotives, possibly working on one division, did not, because of being turned back, on a regular train, make higher monthly mileage than locomotives are making now where they run through on many divisions. To answer this question attention is directed to Fig. 2 where the records have been surveyed for the last 28 years, and where it is possible to study four classes of passenger locomotives handling main-line traffic.

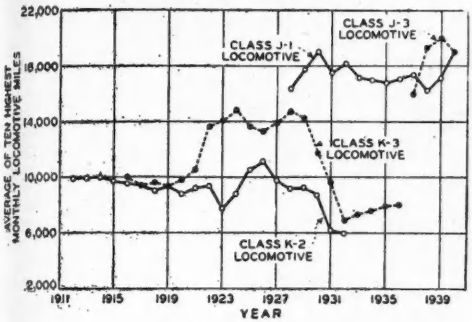


Fig. 2

In making this survey the total mileage made by each locomotive during each month was checked, and the figure illustrates the average miles of the ten locomotives in each class each year which made the greatest total mileage in any one month. For instance, considering the K-2's, one locomotive might make high mileage in June, and surveying July we might find two other engines which made high mileage, while in December we might find two more. These would be considered five of the ten engines making the highest mileage in any one month during the year. The high utilization may be made by one locomotive this month and an entirely different locomotive next month.

It is interesting to note that when a new improved class of power came into service, it not only started to make a record of its own, but suggested ways to improve the performance of the locomotives already in service. The most striking example is the third and fourth classes of power. That is, on the appearance of the fourth class, the mileage of the third class was materially increased until both were fairly close together.

How full utilization is insured.

To insure full utilization of locomotives certain systems have been developed and may be considered under four headings.

1. Checking passenger stations for surplus locomotives. At each passenger terminal station, whether large or small, a study is made periodically covering a spread of two weeks, and all arriving engines and departing trains are charted. As passenger trains run on a regular schedule, this system is found to be practical. Next a schedule is made to use, if possible, the arriving locomotive on a departing train regardless of direction.

2. Checking engine-houses for surplus locomotives. If there are too many locomotives in service, the extra locomotives can only be at the engine-houses, perhaps all at one terminal, but more likely at several scattered terminals, so that it is essential to make a check of engine-house conditions. To do this, the arrival and departure of each locomotive at an engine-house is charted, and considering the performance of the necessary work at the engine-house, the expected average turning time at the house is established. The engine-house in this case can be considered as a store, where profits can be made from goods only if there is a high percentage of turnover of the stock on the shelves. Stock beyond a certain amount is a dead loss; it is a so-called dead stock —not moving—so that above the number of locomotives required at the house any surplus is a loss, not only of the amount it costs to maintain a locomotive ready for service, but also of the fuel represented by the slower movement through the engine-house, and of the overhead on the investment in more locomotives than are necessary.

3. Obtaining capacity performance from the locomotive. There have been radical changes in locomotives in recent years. Counterbalancing has been improved, exhaust tips have been enlarged. Both of these changes indicate to the engine-man that he is not working his engine as hard as he did in previous years. It has become difficult to estimate the capacity at which a locomotive is being used just by listening to the exhaust. When it is necessary to get every pound of available tractive force from a locomotive, experience has demonstrated that it is necessary to give the engine-man some indication by which he will know whether he is working the engine at the maximum capacity for the varying speed. To illustrate, reproductions of actual recording tapes are shown in Fig. 3.

These illustrations were made of 10-, 12-, and 14-car trains, and it will be noted from the curves in solid lines that the distance before the train attained full speed of 70 miles an hour was progressively $8\frac{1}{4}$, 12, and 17 miles. The increase in distance might be expected with increasing weights of trains, yet when specific studies were made in the territory it was found that heavier trains could be accelerated to full speed in 6.1, 7.6 and 8.2 miles.

(*To be continued*).

stripped water

In the preparation of tobacco for good quality cigarettes, the centre stem is stripped from the leaf in the manner shown above, but if this process is not carried out, tobacco including the centre stalk is uneven and contains dust which irritates the throat of the smoker. Similarly with the water required for feeding into water tube boilers it is necessary to strip from it the soluble salts and other impurities in order to secure a non-scaling, non-corrosive feed water. The Permutit "Deminrolit" Process produces a perfect stripped water from any supply without the use of heat or steam.

For full particulars write for publication "Distilled Water without Distillation" to The Permutit Company Limited, Dept. T.B., Permutit House, Gunnersbury Avenue, London, W.4. Telephone: Chiswick 6431.

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

NEW EQUIPMENT

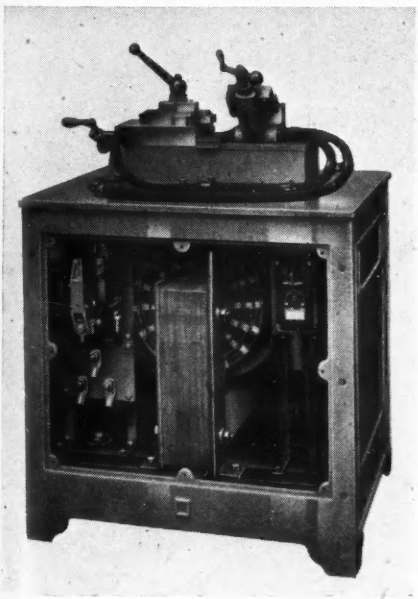
The "Coborn" Electric Tool Tipper.

Messrs. George Cohen, Sons & Co. Ltd. (Stanningley, nr. Leeds) have brought out the "Coborn" tool tipper which permits the brazing of any of the well-known proprietary brands of carbide tips on to tool shanks, by unskilled labour. For this reason it is a useful machine for our war-industry.

The "Coborn" tool tipper is made in two types: Type TA having air cooled heads for dealing with tools up to 1 sq. in. in section and Type TW having water cooled heads, for tools up to 4 sq. in. in section. Both types are simple to control.

The machine can be connected to most public mains being A.C., and can take its supply from 400/440/230 volts—using a single phase from a 3-phase supply, either between phases for the larger tools, or phase-to-neutral for the smaller tools. The main transformer is so designed as to give the highest efficiency over the whole range of the demand.

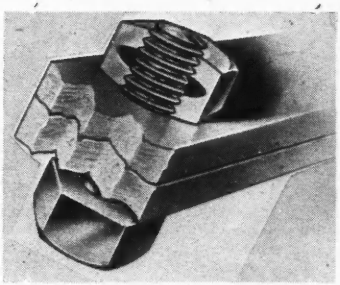
Time for brazing tips on small tools is less than 55 seconds and for maximum cross section of 4 sq. in. less than 5 minutes. Illustrated detailed description, including time—consumption—cross section curves, will be supplied on request.



"Evertite" Nut Locks.

THE increase of speed in all kinds of machinery makes secure fastening of two or more pieces together, in a manner that they can be readily taken apart, a problem of paramount importance. Amongst the numerous fastening designs, extreme simplicity and reliability makes the "Evertite" nut locks, a patent of MESSRS. NUTS & BOLTS (DARLASTON) Ltd., a most welcomed addition to machine design.

The working face of the nut is made convex and a V annular groove or suitable section is cut a few threads up from the convex face, as shown in the Figure. When the nut is screwed home, pressure on the convex face forces the portion of the nut below the groove towards the upper part, so slightly closing the V groove and at the same time reducing the diameter of the lower threaded portion, thus gripping the thread and giving an additional lock.



CMV 40 Vertical Milling Machines.

Two models of the CMV 40 Vertical Milling Machines are announced by MESSRS. KENDALL & GENT (1920), Ltd. One has a standard milling head with simplified speed selection, the other with long speed range. The standard head model has a speed range of from 9.5 to 238 r.p.m. and a great improvement is claimed by the elimination of the usual conversion of spindle revolution to surface speed; nine spindle speeds, not in geometrical progression, but in the progression of cutter diameters from 1½ to 12 ins. are obtained from a single control lever. It is, therefore, only necessary for the operator to set the speed selection to the diameter of cutter in use.

The long speed range model has a speed range of from 15 to 840 r.p.m., the selection being solely by levers. A lever on one side of the head gives high or low range speeds and a selector on the opposite side the particular speed required from either range.

The two machines are otherwise similar in construction incorporating many features promoting reliability and accuracy of operation and easy controlling. Some of these are: Audible slipping clutch giving warning when head contacts infinitely variable depth stop; instantly detachable surface speed slip gears; infinitely adjustable positive dead stop; good protection of mechanism and slides from swarf; all geared units have incorporated oil baths, electrical directional feed selection, etc.

Prospectuses obtainable on request.

Multi-chamber type Core Stove.

Continuous production without continuous stand-by attendance is a desirable feature of war-time production, offered by the "Newstad" multi-chamber type core stove, manufactured by Modern Furnaces and Stoves Ltd. (275, Long Acre, Nechells, Birmingham, 7). The chambers are connected in parallel to two under floor ducts. Each chamber can be regulated separately or shut off altogether. Thus easy extension is possible by adding further chambers, if required.

For small and medium size cores the "Traykor" type core stove is recommended, and for somewhat larger works the "Drawkor" type. All types incorporate innovations of comparatively recent date, ensuring sound and clean casting by the quality of core drying.

CATALOGUES RECEIVED

Structural Steel-Asbestos Fire Protection.

In the line of fire protection materials, the leaflet published by Durasteel Roofs Ltd., makes a very interesting literature. Their comparatively recent product, 3DF2, is essentially a composite flat sheeting consisting of two facing sheets of light gauge steel securely keyed together by patented process to a highly compressed asbestos composition core. It combines thus the outstanding qualities of strength (steel) and fire resistance (asbestos) in a light and compact form. With it countless types of partitioning, sub-divisioning, and general constructional work can be undertaken. Compared with older type of materials such as bricks, or non-rigid building boards, it saves space and gives structural strength.

The high content of pure asbestos fibre in the core ensures, it is claimed, utmost degree of fire and heat resistance. Moisture and air vesicles are eliminated by the heavy pressure of processing, removing the danger of bursting under exposure of heat.

The indentations formed on the steel surface of 3DF2 make a characteristic and attractive pattern, and the sheets may be painted to conform to existing finishes when used for interior structural work.

In addition to its head insulating properties, Durasteel 3DF2 is non-resonant, and affords a great improvement in sound insulation over sheet steel panelling for roofing.

Requests for detailed catalogues should be sent to Durasteel Roofs Ltd., Oldfield Lane, Greenford, Middx.

B.C.E. Earth Tester.

THE vast number of portable electrical tools now in use has considerably increased the number of accidents. Protection against these is a most important requirement, and it is for this reason that THE BRITISH CENTRAL ELECTRICAL CO. LTD. (6 and 8 Rosebery Ave., E.C.1.) have designed an Earth Tester which, by operating with 15 amp. load, is claimed to give full protection against faulty contacts, even in such instances when the normal bell and battery or the lamp test would fail.

Main features of the tester are simplicity and reliability; the first is achieved by employing press button control of the tester, the second by passing full load through the tool to be tested and the positive indication of the quality of earth. Poor earth and intermittent contact or no earth can be at once ascertained by the ammeter reading or the lighting up of a red lamp respectively.

For particulars, applications should be forwarded to The National Publicity Co. Ltd., 43-44 Shoe Lane, E.C.4.

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